SCIENCE

FOR BETTER LIVING

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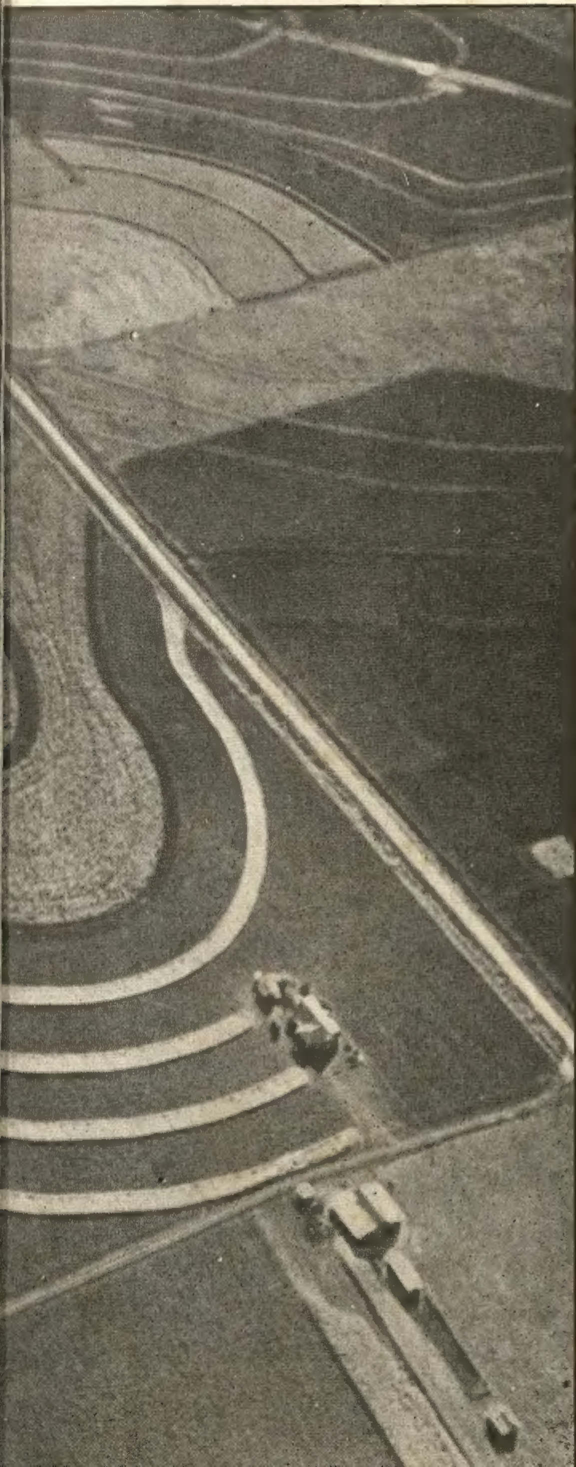
SCIENCE FOR BETTER LIVING

Front endpaper THE WORLD OF THE ASTRONOMICALLY LARGE. *The planet Saturn from its small but near satellite Mimas. The rings, while wide, are surprisingly thin; nevertheless they produce a deep shadow on Saturn. This view reproduces one of the illustrations in* The Conquest of Space *by Chesley Bonestell and Willi Ley. Used by arrangement with the Viking Press. Copyright 1944 by Chesley Bonestell.*

Back endpaper THE WORLD OF THE MICROSCOPICALLY SMALL. *Three crystals of substances often taken into the human body:* (Left) *Rodlike crystals of a compound of thiamine, one of the B vitamins.* (Center) *A single sugar crystal.* (Right) *Needle-shaped crystals of a compound of another B vitamin, niacin. Both vitamin crystals reproduced by courtesy of E. R. Squibb and Sons. The sugar crystal used by courtesy of the Sugar Research Foundation, Inc.*

SCIENCE FOR

BETTER LIVING



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Preface

This is the Age of Science. There are today few phases of living in which we do not turn to the scientist for aid and comfort. He has become a central figure in our society. For that reason, if for no other, it is important for every person to understand how the scientist works—his goals, his methods, his limitations. This is perhaps the central goal of this book.

Science for Better Living is a *general* science book. It is not a survey of all the sciences. It is not a mere orientation book designed hopefully to encourage enrollment in later science courses. It is a general science book in the sense that it deals with basic problems of living and the general principles by which all scientists work at solving these problems.

The table of contents reveals units which state the problems of living—problems such as *Increasing Man's Life Span* and *Improving Biologic Production.* In these units and others, the materials of several sciences are drawn together. For example, in the first unit, *Man—The Basic Resource*, anthropology, physiology, and psychology contribute to the student's understanding of man's place in the world.

The organization of this book, its general outline as well as the detailed content of the units, has been determined by the basic goal of showing how scientists in this Age of Science work on the problems of our physical life. This goal has provided a way of deciding what detail to include.

One of the most spectacular and disturbing aspects of modern science is the amazing acceleration in the development of new knowledge. No one person can keep up with the new information even within one basic science. The modern researcher is becoming a specialist in one tiny corner of his field. If this is the effect on learned men, what is the effect on textbooks for students? No one text can retail all the information on the subjects it introduces. But what detail is to be included and what is to be left out?

The age and abilities and background of the students provide some limitation. But the scientific information now available and within the comprehension of young people is still far too great in scope to come within one book. Some authors have attempted to meet the problem by including as much of this enormous detail as their pages will hold. The authors of *Science for Better Living* have resisted the impulse to be encyclopedic. They have asked which details from the many available will give students the best insight into how scientists work to solve our problems of living. These they have included; the rest they have omitted.

Science is not merely a collection of facts to be memorized. Too many adults of this day can recall memorizing the "facts" of their youth only to find them one by one disproved and abandoned. It has been said that the modern scientist announcing a new theory or investigation fully expects that in his lifetime his "facts" may be disproved. Science is a self-correcting body of knowledge. The methods of self-correction, the methods of investigation, are at least as important as the "facts" that scientists have discovered about our world.

Science is scientists; that is, men and women at work. This book shows them at work. From the history of science the reader here learns not only the successes of the great scientists of the past, but their mistakes as well. In these pages the student sees science as the work of men and women, from Thales and Archimedes to Fleming and Fermi.

You would expect that a book written from this point of view would be written simply. The technical terms, those that need definition, do not exceed 550. All of these are defined and pronounced when they first appear. They are also listed for review at the end of the chapter. They are all caught up in the Glossary for later reference. Limitation of detail and limitation of terminology make for simpler reading. But primarily, this book is easy to read because the authors have taken time and space to explain fully each concept they introduce. Freed from the pressure of covering all the facts in every field of science, they are at leisure to proceed slowly and surely in their exposition.

Activities and experiments have been written into the body of the text. They may be read with the accompanying diagrams as part of the text account and they may be demonstrated by the teacher or performed by students at home or in the laboratory. They do not interrupt; they are a part of the exposition. At the end of each chapter, more activities are provided to give students further acquaintance with labora-

tory and field. There are also four chapters on science hobbies to provide further exploration and added opportunities to learn by doing. A separate workbook containing a great number of rich, meaningful science experiences has been written for this text.

The drama of science is evident in these pages. For science is a spectacular drama, the story of man learning to control himself and the physical world. In this drama, man is the central character, our basic resource. And that, incidentally, is the subject of the first unit.

The statement is credited to Newton that he was able to see more because he stood on the shoulders of others. Similarly the authors of this book stand on the experienced shoulders of many without whose help, encouragement, and criticism this book could not have been written: Miss Edna Craig, Newburgh High School, Newburgh, New York; Dr. Irene Jaworski, teacher of English at Forest Hills High School, Forest Hills, New York; Dr. C. W. Mattison, Forestry Education Consultant, U.S. Forest Service; Miss Evelyn Morholt, Forest Hills High School, Forest Hills, New York; Mr. Hyman Ruchlis, Chairman, Physical Science, Bushwick High School, Brooklyn, New York; Miss Ella Thea Smith, High School, Salem, Ohio; Miss Mildred Waltrip, whose drawings contribute so much to the teaching qualities of this book; the many high school students who read parts of the manuscript at various stages in its development; the wives and friends of the authors who helped with their critical judgment and cheerful encouragement; and the various persons who have contributed illustrations which we have acknowledged in the text.

THE AUTHORS

To fellow students

You may think it strange for the authors to address you as fellow students. Although as teachers and writers we are further advanced in scientific work than you, we are still your fellow students in science. Anyone whose lifework is in the field of science must always be a student. New facts are discovered constantly in every scientific field. Science never stands still. Scientists are never satisfied for long with their explanations of facts.

In 1942 in a corner of Stagg Field, once a football stadium at the University of Chicago, scientists first built an atomic pile in which large amounts of atomic energy were produced. At that moment we entered the Atomic Age. Three years later the first atomic bomb fell. Yet atomic scientists say today that they really do not know what goes on inside the atom. In every part of this country they are at work in laboratories studying the atom and its parts. Yet even though scientists are not satisfied with their knowledge, they have done much to change our ways of living. The airplane roaring overhead is a product of science. So are automobiles and the pavements on which they run.

Think of the things which you have done during the past twenty-four hours. The tooth paste with which you brush your teeth, the car which brought you to school, the telephone call you made—all were made possible through the work of scientists. The movie you saw and the radio you listened to are products of science. Think of the foods you ate—meat, milk, or fruit. Scientists have been responsible for improving the quality and increasing the variety of foods.

Even in the short time you have been alive, science has made great changes in our ways of living. Medical science has learned to control many of the diseases of childhood. It has improved child nutrition. As a

result, you are stronger and heavier than a boy or girl of your parents' generation. You will see more things, do more things, visit more places than a boy or girl possibly could have twenty-five years ago. Your life is richer and more varied than it would have been twenty-five years ago. And because of new advances in medical science, the boys and girls of your generation will live longer than the people of any generation before you.

"Very well," you say, "we are safe. Our scientists will solve our problems for us." Nothing could be further from the truth.

Scientists can and do solve their problems. Only you and the millions of people like you can solve your problems and the problems of society. Scientists can give us tools, but we must use them. Scientists, for example, can tell us what to do to stay healthy, but only we can do it. Scientific information is of little value unless it is put to use to serve ourselves, to fight disease, to overcome prejudice and superstition.

As you use this book, as you take part in the experiences it offers you and do the work it suggests in the laboratory and field, you will get the full force of the report one scientist made to President Franklin D. Roosevelt:

"Advances in science when put to practical use mean more jobs, higher wages, shorter hours, more abundant crops, more leisure for recreation, for study, for learning how to live without the deadening drudgery which has been the burden of the common man for ages past. Advances in science will also bring higher standards of living, will lead to the prevention or cure of diseases, will promote conservation of our limited national resources, and will assure means of defense against aggression. . . .

"Science by itself provides no panacea for individual, social, and economic ills. . . . But without scientific progress no amount of achievement in other directions can insure our health, prosperity, and security as a nation in the modern world."[1]

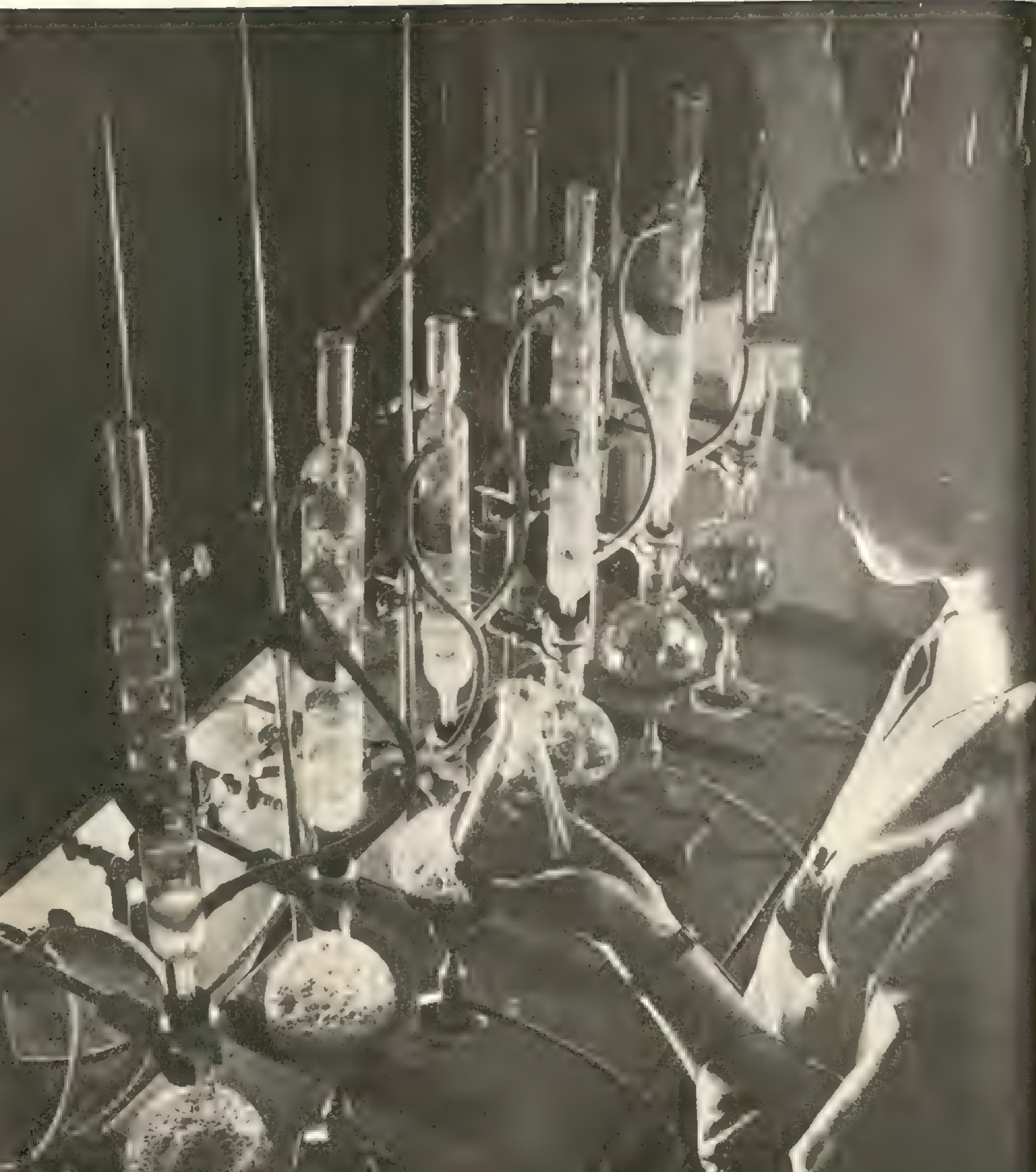
THE AUTHORS

[1] Vannevar Bush, Director, Office of Scientific Research and Development, "Science, The Endless Frontier" (Report to President Franklin D. Roosevelt).

CONTENTS

UNIT ONE

MAN—THE BASIC RESOURCE



A young laboratory worker testing the effect of a dye on different metals. Does the apparatus work by itself? Does it invent itself? No. Behind it is man—always the world's basic resource. (E. I. du Pont de Nemours and Company)

What use is a newborn child?

One day the great English scientist, Michael Faraday, was demonstrating a new invention before a distinguished audience. As Faraday finished his demonstration, Prime Minister Gladstone is said to have asked, "What use is this invention of yours?"

Faraday replied, "What use is a newborn child?"

Faraday was saying in effect, "You can't tell what a newborn child will become. You can't tell whether he will become a criminal, a scientist, a writer, or a statesman. And, in the same way, you can't tell whether a new invention will help or harm mankind. Just as a child has to learn many things before he is a useful person, so we have to learn how to use an invention before it is any good to us."

A newborn child does grow into an adult. And as an adult, he takes his place with others in the society in which he lives.

Compare man with other animals. The elephant is so much stronger, so much bigger that he can crush a man in the coils of his trunk; he can uproot trees. The tiger can run faster, and has more powerful muscles. A shark can outswim man and a goat can outclimb him.

Yet man has one part of his body which makes him superior to all of these other animals. This organ makes it possible for him to outstrip the eagle in the air with his airplane, to outrun the shark in the water with his ships, to outspeed the hare or tiger with his automobile, and with a bulldozer to beat the elephant in uprooting trees. This organ enables him to build cities, blast mountains, turn desert into farm land. This organ is his brain.

It is even more important for man to make the best use of his first resource—that is, himself, his brain, and his capacity for good—than it is to conserve his natural resources: his coal, oil, metals, water, soil. For men themselves will improve the world—or destroy it.

In this unit you will travel with the Dutch scientist Dubois to discover the bones of the ancient Java ape man. You will wonder how

the other ancient men who parade through Chapter 1 lived and worked.

In Chapter 2 you will read how man can become master of himself through learning. You will ask yourself, "Do I make the most of my opportunities?" In the final chapter of this unit, you will become acquainted with man's modern tool, science and its methods. It is this tool, more than any other, which has helped man gain increasing mastery over himself and his surroundings.

In this unit, then, you will look at yourself as a resource. You will look at yourself as a person important to your community. For *you and others like you* are what we are talking about when we say that man's basic resource is man.

CHAPTER 1

MAN—ANCIENT TO MODERN

In southern France there is a cave which specially interests scientists. Here in this cave, men lived thousands of years ago. There are no written records of their lives, no history books. There are only a few pictures which they drew upon the walls of the cave.

How did these pictures come there? Sometime long ago a man stood in this cave working in the light of a crude lamp. With remarkable skill he worked into the wall a picture of a strange animal (Fig. 1). There is no animal like it alive today.

Was it a real animal or only a product of the artist's imagination? Scientists have found the answer to this question. Exploring in various parts of the world, they have dug up bones of great animals long since dead. You can see skeletons of these animals, as scientists have reconstructed them, at the Chicago Field Museum and at the American Museum of Natural History in New York (Fig. 2). These animals are called mammoths. Some years ago in Siberia a pack of dogs discovered a mammoth with both flesh and bones preserved in ice. The evidence shows that early man really saw such animals as he drew upon the walls of his cave.

EARLY MAN

Early in the twentieth century, over in the Rancho La Brea in California, workmen were digging in asphalt, or pitch. Now and then a squirrel or chicken became entangled in the soft pitch. Coyotes and other large animals who came to feed on the unfortunate creatures were trapped in their turn. All were swallowed by the asphalt. Finally the pit became unprofitable to work and the scientists had their turn. What a treasure they dug up!

They found well-preserved remains of animals and other living things which existed before history was written. They found the remains of huge saber-toothed tigers and gigantic sloths. They discovered the bones of ancient horses which had been entangled in the asphalt and trapped to their death thousands of years ago. Remains of ancient life are called *fossils*. And they tell us that living things of the past were not the same as those of the present.

RECORDS IN THE ROCKS

Have you ever seen a living land animal 70 feet long, weighing 40 to 60

1 *A reproduction of a painting which shows Cro-Magnon artists at work on a wall of a cave in Font de Gaume, France. What animal are they picturing?* (*American Museum of Natural History*)

tons? No living man has. Yet a study of fossils shows us that such animals existed long before man came on the scene. The fossil bones of giant reptiles have been found embedded in rock. These bones have been carefully dug out and put together in museum laboratories. What do we find in these museums when we visit them? We gaze with awe at reptiles like the *Brontosaurus* (brŏn'tō sô'rŭs) almost 70 feet long (Fig. 3). Alive it must have

2 *Compare these reconstructions of the mammoth, from actual skeletons, with drawings by Cro-Magnon man. To what animal may the extinct mammoth be compared?* (*American Museum of Natural History*)

weighed 40 to 60 tons. Here is the great *Tyrannosaurus rex* (tĭ răn′ô sô′rŭs rĕks), the terror of all animals, with its huge head filled with awesome teeth. It stood 18 feet high, no less. Here are huge flying reptiles, pterodactyls (tĕr ô dăk′-tĭlz). Here are small reptiles, no bigger than fence lizards. These animals no longer exist. They lived some hundred million years ago according to all the ways of measurement we have. Living reptiles, snakes, turtles, and lizards are small indeed by comparison.

3 *An extinct reptile, the dinosaur* Brontosaurus. *This huge animal was so large that it might have more than filled an ordinary classroom. Why did the dinosaurs die out?*

HUNTING FOR FOSSILS

An exploration for fossils is exciting. Is it by caravan in the Gobi Desert? Is it by car to the rich fossil beds of the Wyoming hills? You will find scientists in the field working painstakingly with hammer and chisel as they come upon a find. The artists and photographers make a complete record (Fig. 4).

Why don't you go on a fossil hunt? Make a day of it with your friends. Take your lunch, a hammer, and a book on fossils and go to the nearest stone quarry or coalyard. Much of your material will be found lying about in broken rock or coal. You may not find any fossils but then there is the fun of hunting. It is all the more exciting when you find them.

What will you look for? You cannot expect to find the huge bones of ancient reptiles. But you may find the fossil imprints of fern leaves or the casts of ancient shelled animals, like those in Fig. 5. Perhaps your school has a collection of fossils that you might examine to guide you. Or better yet, if you live near a museum go to see its fossil collection.

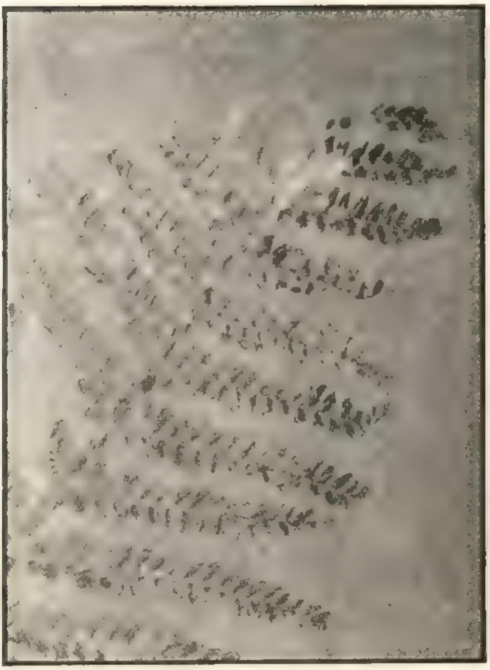
4 *Collecting fossils of dinosaurs. Can you see the huge bones embedded in rock? Notice how carefully the men work.* (*American Museum of Natural History*)

THE JAVA MAN

The fossils of ancient man are very rare. Scientists have not been able to find many that are well preserved. Ancient men were usually buried at the surface where their bones were easily destroyed. Further, the evidence indicates that early man lived in remote parts of Asia or Africa.

But if you had been alive in 1894 and lucky enough to go on a journey with the Dutch scientist Dubois (dü'bwä'), you would have been hunting with him for fossils of man. The expedition wandered along a river in Java, which lies off the coast of southeast Asia. After many years of search, Dubois was finally rewarded by an exciting discovery. He found the top of a skull, some teeth, and a thighbone. "How disappointing," you say. "What can one do with such fragments?" A great deal, if you are an expert. Scientists who study fossils can reconstruct an entire skeleton from such fragments. What is more, knowing the structure of the bones, they can clothe the skeleton with imitation muscle and skin (Fig. 6).

Scientists were able to reconstruct the body of a primitive-looking man from the skull, teeth, and thighbone Dubois found. They think he resembled Fig. 6 (left). You can see that this Java man resembled modern man in many respects. But he was also different from modern man. His skull could not have held more than two-thirds of the brain you have now (Fig. 7). Also his thigh-

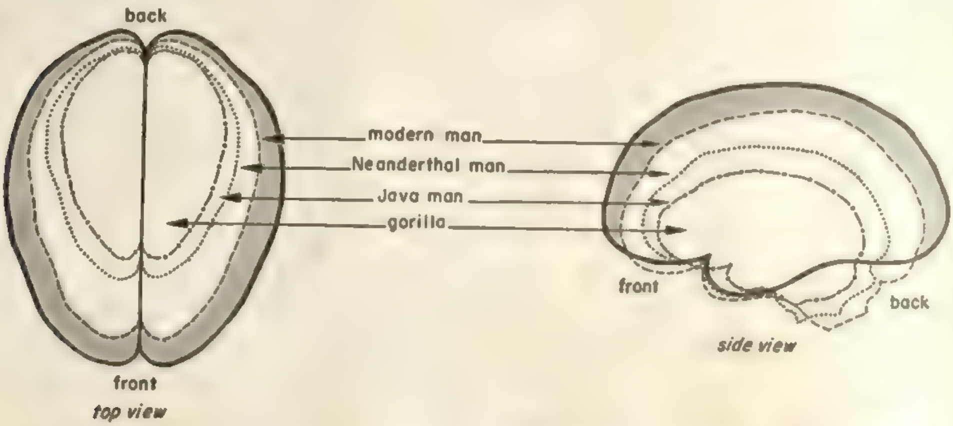


5 *Typical widespread fossils: a seed fern* (left) *and shells* (right). *You may find similar fossils in your region.* (*Marion A. Cox*)

6 *Photographs of early man as reconstructed by scientists. On the* left *is Java man; on the* right *is Neanderthal man.* (*American Museum of Natural History*)

bone was curved, so that he must have walked with a stoop. Our thighbones are straight, enabling us to walk erect. And although the record in the rocks is meager, we do know that the Java man lived about 500,000 to 1,000,000 years ago.

man as he had tools to help him live better. In the refuse before his caves, we find broken tools such as scrapers and spears (Fig. 8). With his crude spears, he hunted the animals which gave him meat. He had crude scrapers perhaps used to scrape the meat from



7 *This diagram compares the size of the brains of different men and the gorilla. How is the size of the brain related to the amount of control over the environment?*

the animal skins so that they could be worn as clothing. In other words, there is evidence that Neanderthal man was beginning to learn how to control his surroundings or environment.

We know very little about the way Java man lived. Perhaps he used a club to protect himself against wild animals and to kill game. His brain, small as it was, probably enabled him to outwit the animals about him.

MAN IN THE NEANDER VALLEY

From fossils of men discovered in the Neander valley in southern Germany, scientists have reconstructed a man who was closer to modern man in many ways than Java man. From the skeletons found we can reconstruct a man who must have had a low forehead with heavy ridges over the eyes (Fig. 6). His heavy jaws and large broad nose gave him a ferocious appearance. He was stooped and only five and a half feet tall, but he had powerful muscles.

Neanderthal (nå än′dẽr täl′) man was probably more advanced than Java

Scientists agree that Neanderthal man spread throughout Europe about 100,000 years ago. Some scientists think that Neanderthal man is our ancestor. Others do not.

CRO-MAGNON MAN

However, there is no doubt about the kind of men who peopled Europe after the Neanderthal man. There are many fossils of a magnificent man found in the Cro-Magnon (krō′må′nyôɴ′) valley in France. These men existed about 35,000 to 50,000 years ago. They were tall and well proportioned. Their skulls were large enough to hold a brain as large as ours. They studied the

animal life about them and painted excellent likenesses of woolly mammoths, reindeer, and horses on the walls of the caves in which they lived (Fig. 1).

Cro-Magnon man fished the streams and hunted with spear, bow, and arrow; he forced his environment to yield him food. He had useful tools of bone and ivory. Some of these tools were shaped like awls, with which Cro-Magnon man may have sewed his fur clothing. In addition there is evidence that Cro-Magnon man knew how to use fire for cooking and warmth.

The fact that Cro-Magnon man had fire, tools, and clothing shows that he was increasing his control over his environment. That is, a cold environment could not drive him away; he could keep himself warm with fire and clothing. The animals in his environment could not drive him away; he had good spears, better than those of Neanderthal man, to protect himself.

One part of man's story is summed up in his struggle to control his environment. It began with the earliest of men such as the Java man and continues even now as man pushes ever forward, into outlying regions like the South Pole, down into the deepest seas, and into the air. Every scientific discovery which helps man make his home a capsule of perfect weather takes man nearer his main goal—mastery over his environment. Cro-Magnon man, like those before him, made a contribution to man's attempts to master his environment.

Although Cro-Magnon man was far advanced over the Neanderthal, he was not able to survive. No one knows why he disappeared. But Cro-Magnon man was a modern man in brain and body —even as you are.

MAN'S SPECIAL TRAITS

You are a good example of modern man. Scientists say all of us who are on earth today belong to one kind of man, called *Homo sapiens* (hō′mō sā′pĭ ĕnz).

MODERN MAN—*HOMO SAPIENS*

Living things which belong to a recognizable kind, which are alike in most physical traits, which breed freely with each other, are said to belong to one *species* (spē′shēz). All dogs belong to one species; so do all horses, all cultivated oat plants, all the com-

8

This is the way one artist imagined a Neanderthal family in front of the cave in which they lived. What evidence is there in the picture that Neanderthal man had some control over his environment? (*American Museum of Natural History*)

mon house cats. Each species is given a Latin name by scientists. Thus the common house cat is *Felis domesticus;* the cultivated oat plant *Avena sativa.* All men on this earth belong to one species—*Homo sapiens.* And all of the two billion or more people living on this earth came from the seven million or so which scientists estimate lived some 25,000 to 50,000 years ago.

MAN'S FLEXIBLE THUMB

You, as an example of *Homo sapiens,* have some very definite and interesting physical traits which set you apart from examples of other species. For instance, have you ever paid careful attention to your thumb? Touch your little finger with it. Easy? Yes, but you are the only animal living who can do it easily. Suppose you couldn't? You could not use a pencil well. Try writing while you hold your thumb like the other fingers. Try threading a needle without using it; it is very difficult to do these tasks without using your thumb opposite the other fingers. You can see that the thumb opposes the other fingers. This physical trait enables man to use tools as no other animal in existence can (Fig. 9).

THE SPEECH APPARATUS

A second important physical trait which sets man apart is his ability to make different sounds with the vocal cords in his voice box, or *larynx* (lăr′ĭngks), his tongue, and his lips. Can you imagine a civilization without speech? By his speech man tells his wants, his hopes, his ideas to others. He can teach others. Other animals like chickens, birds, chimpanzees, and crickets can communicate with their own kind in a crude way. But man's sounds can be varied to explain ideas and feelings elaborately and accurately. The speech apparatus enables men to pass on what they learn to the next generation. When writing was invented, man was able to record his speech and pass knowledge on more effectively. As you read this book, you are taking part in one of man's most important methods of controlling his environment and passing on knowledge of that environment to new generations.

MAN'S BIG BRAIN

Without his brain, man could not use tools even with his flexible thumbs, and his versatile larynx would be wasted. For tools have to be invented and languages created. In short, civilized living depends on man's big brain and his ability to use it in thinking.

Here is an idea of what thinking means. First, shut your eyes. Call up a mental picture of six gray elephants in a row, each one standing on his hind legs. Obviously, there were not six elephants in your brain. Yet you "saw" them, or you may say you thought about them. In thinking you can produce images of things you have experienced in the past; in this case you are producing images of elephants.

Just as you can think about things you have seen, you can think about things you haven't seen. For instance, shut your eyes and imagine a white elephant—white as your white shirt. The chances are that you have never seen an elephant as white as a white shirt but we know that you are able to think of one.

There's nothing hard about that, you say. But this is what you have done. You have taken away the color *white* as it was related to the white shirt and related it to the elephant. You have

A trained chimpanzee trying to thread a needle. Chimpanzees do not have a thumb as flexible as yours. Notice how the chimpanzee holds the needle. (American Museum of Natural History)

abstracted, or taken away, the idea of *whiteness* from its original object and are now using it in relation to a new object. If you wanted to you could think of white elephants, white snakes, even white grass. Yes, shut your eyes and think of a rolling field of white grass.

In other words, when you use the idea *whiteness* apart from your original experience (white shirt) you have abstracted it and combined it with another idea. This is an example of one important kind of thinking. It doesn't explain all types of thinking but it helps explain how man invents or creates. For abstraction allows men to put old ideas together in a new way. In the example of abstraction we gave you, you put the old idea *whiteness* together with the old idea *elephant* and got the new idea of *white elephant*.

The ancient man who had to cross a stream which was in his way faced a problem of invention. Perhaps he remembered seeing a tree which had accidentally fallen across a stream. He had never before put a tree across a stream. Yet now the idea came to him. He threw a trunk across the stream. He had invented a bridge.

MEMORY AND INVENTION

Of equal importance with this ability to abstract ideas is man's ability to store experience, to remember things. As you well know, your memory is essential to your happiness; without memory you could not learn. You can remember

what you have read. You can remember what happened five years ago, what has happened to others ahead of you. You can use these memories to imagine what may be ahead for you. Thus you can plan ahead.

Here is a demonstration of your ability to invent. We're going to give you several facts; from these you will deduce the ideas you need and invent a kind of weather forecaster. The facts are:

1. Cobalt chloride is a substance which is easily produced.

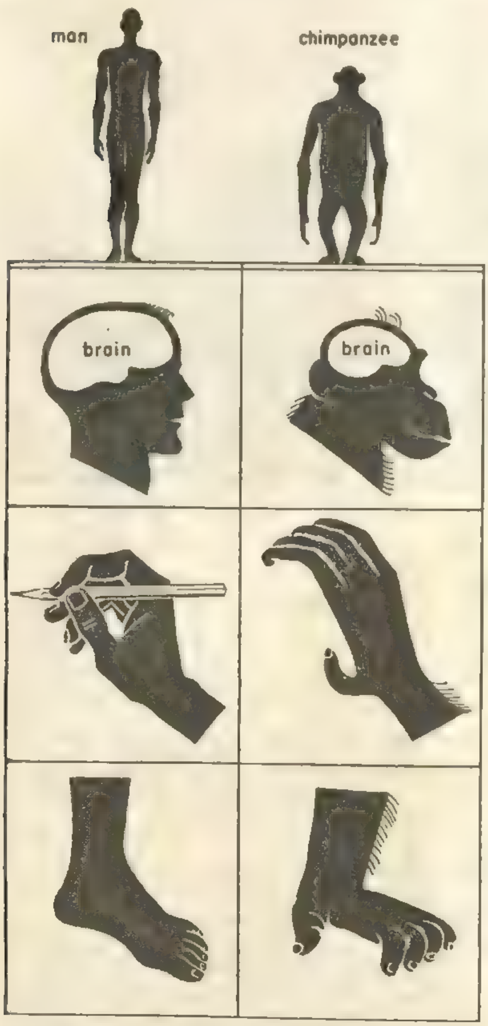
2. When it is placed in the presence of moisture, it turns pink.

3. When it is in dry surroundings, it turns blue.

4. It dissolves in water.

5. It may be used to dye pieces of white cloth, gauze, or linen.

On the basis of these five facts, can you invent a weather instrument which will help in determining whether there is little or much moisture in the air?



10 *Diagrams comparing three characteristics of man and the chimpanzee. How does the foot influence where each lives?*

MAN'S PHYSICAL TRAITS MAKE HIM A SOCIAL ANIMAL

Early in his development man must have sought every possible protection against the wild animals around him. He must have learned early to band with others of his kind against the huge beasts who could conquer him when he was alone. And because he had speech, he learned to exchange ideas with other men. Early men thus were knit together in groups of some sort.

Soon men learned to co-operate with each other. They learned to do different things (specialization); some hunted, others tended the fires, others stood guard to protect women and children. Out of co-operation and specialization came the start of the early community. Men lived together and worked in different ways together to help themselves and to help each other.

Thus man's brain and his ability to speak enable him to live with others. He is a social animal. But the social life of man is fundamentally different from that of other animals who live together: the bees, or ants, or herds of bison or giraffes. Man is able to create and react to new ideas. He is able to change himself and his surroundings. He depends

upon others for food and clothing, for medical aid, for entertainment, for advice. He works with others as a social animal. In general, he lives and co-operates with others in his towns, villages, cities, states, and countries. His co-operation makes government possible.

We have touched just briefly on three main characteristics which help make man what he is, indeed which make you what you are. These above all others make him *Homo sapiens*. In Fig. 10 and Table I, compare man with one of the higher animals, the apes. Despite some similarities, you see that man's brain and his hands are far superior. The apes are able to exert little control over their environment. Man can build a house, but an ape lives in a tree at the mercy of the weather. Because man has these special organs and special abilities, he can control the apes and other animals. And even more important, as you will learn throughout this book, man has been able not only to control his environment, but even to change it. Every chapter in this book tells you how man is gaining mastery over his environment.

WHERE MEN LIVE

In the preceding section, we have considered men under the heading *Homo sapiens*. This was a valuable way of looking at man while we were considering the characteristics which set him apart from all other animals. We saw that man's brain, his hands, and his speech apparatus have placed him where he is today. Man has spread over the earth; he can now live almost anywhere on it. Fossils tell us, however, that at one time he was restricted to the tropics where it was warm, where food was plentiful. Because man had no tools and no clothes, he had to live in the tropics. Here he could simply gather the food he needed and survive with little shelter and clothing.

MAN EVERYWHERE

Scientists know that when food and other conditions (such as temperature) are favorable, animals multiply and spread. It may have been the same with man. He reproduced his kind until he spread throughout the tropics. In order to live in colder climates, he had to take warmth with him.

Table I. MAN AND THE APES

Human characteristics	Ape characteristics
1 Ground-living	1 Tree-dwelling; adapted to living chiefly in trees
2 Walks on two legs	2 Walks on all fours
3 Shorter arms; longer legs as compared with apes	3 Longer arms and shorter legs as compared with man
4 Development of the thumb, which increases ability to use tools	4 Thumb not as well developed as man's
5 Designs homes	5 Lives in trees
6 High development of brain	6 Brain far inferior to man
7 Well-developed speech	7 No speech; makes sounds; uses gestures

what you have read. You can remember what happened five years ago, what has happened to others ahead of you. You can use these memories to imagine what may be ahead for you. Thus you can plan ahead.

Here is a demonstration of your ability to invent. We're going to give you several facts; from these you will deduce the ideas you need and invent a kind of weather forecaster. The facts are:

1. Cobalt chloride is a substance which is easily produced.

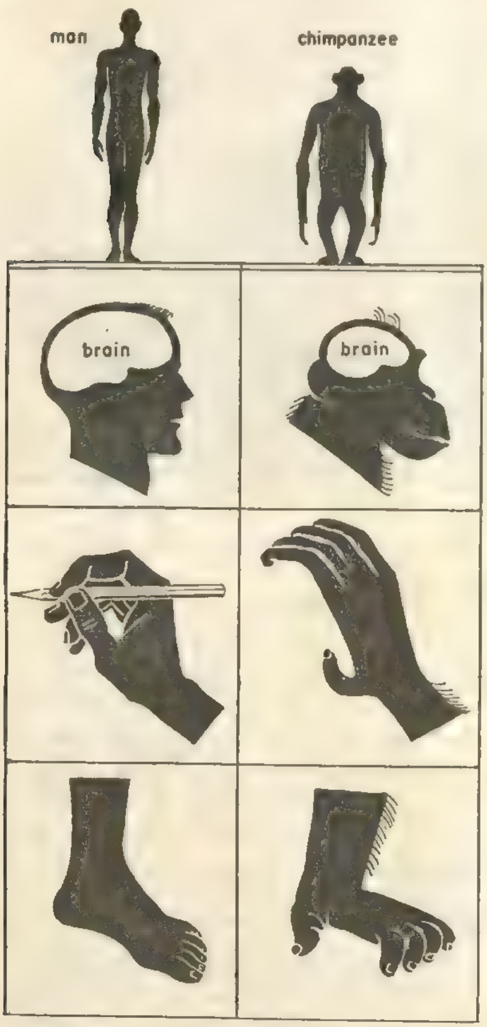
2. When it is placed in the presence of moisture, it turns pink.

3. When it is in dry surroundings, it turns blue.

4. It dissolves in water.

5. It may be used to dye pieces of white cloth, gauze, or linen.

On the basis of these five facts, can you invent a weather instrument which will help in determining whether there is little or much moisture in the air?



10 *Diagrams comparing three characteristics of man and the chimpanzee. How does the foot influence where each lives?*

MAN'S PHYSICAL TRAITS MAKE HIM A SOCIAL ANIMAL

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Above all other things man needed fire before he could live in a climate colder than that of the tropics. The use of fire to keep people warm was one of man's greatest inventions. Can you imagine how terrifying a fire might be if you came upon it for the first time and no one could tell you what it was? When lightning or some other cause started a fire, the early people watched with fear as it burned trees and grass. But finally men discovered that fire could be controlled so it would keep them warm. These men, or others, learned how to keep fire alive. Later men learned to make fires. With this knowledge they were equipped to move out into colder regions where fires were needed.

Thus fire helped men to spread over the earth. Today man's ability to control fire, to produce warmth and keep it in the house or shelter he builds enables him to live everywhere in the cold regions. Man has become the most widely distributed species of animal on earth.

MEN OVER THE EARTH

Are the two billion people on this earth distributed evenly? Let us see. It has been estimated that if all human beings were spread out evenly on the land surface, we would have an average of about 30–35 per square mile. This is plenty of land for 30–35 people, you may say. However, a good many people would die because they would be placed on deserts, swamps, and mountains where they could not even exist, much less support themselves.

Partly because land varies in its usefulness, different countries have different distributions of population. In Australia, for instance, there is an average of two persons per square mile. Remember, however, that a good deal of Australia is land which cannot support human life. In Belgium the average is about 630 persons per square mile, while England has an average of 650. In the United States there is an average of 38 per square mile, while in Alaska there is an average of 1 per 10 square miles. In China the distribution is an average of 100 per square mile. This figure is misleading because China is a country of vast mountains and deserts; in these areas even a poor and meager existence is difficult to get.

You see, therefore, that although men are distributed all over the world, they are not evenly distributed. Men live in greatest numbers where life is easiest. In these places the temperature is neither too hot nor too cold for people, the climate is neither too wet nor too dry, and food plants can be grown easily.

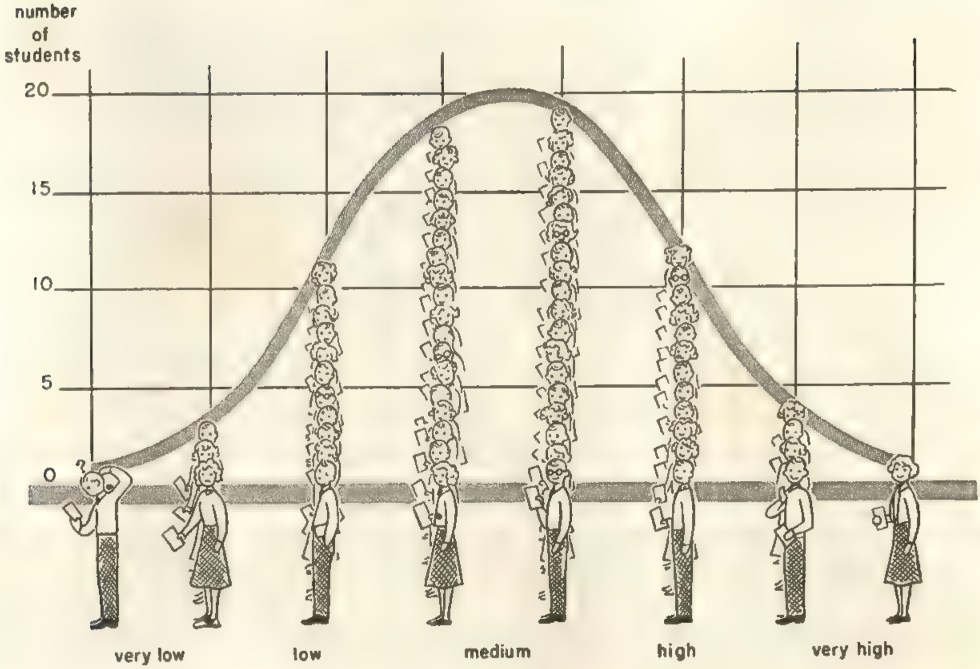
SIMILARITIES AND DIFFERENCES AMONG MEN

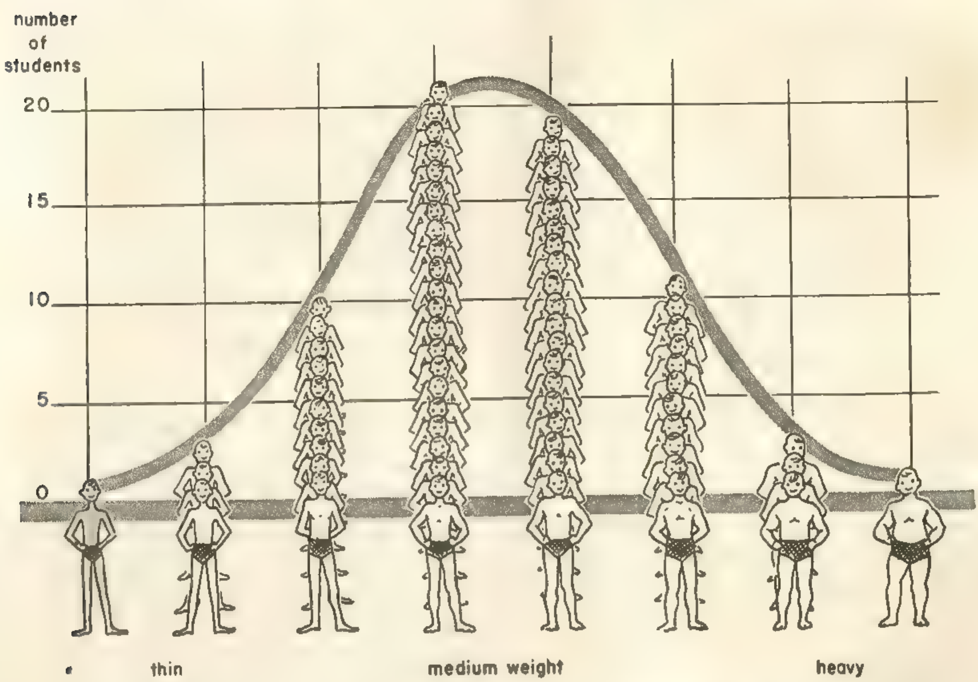
If you were to examine a fair sample of people from all over the world, what would you find? You would note that all of them have the same physical structures. For instance, all (except those who may have been injured) have eyes, eyelids, ears, noses, hands, nails, and countless other structures. You would be convinced that all people have a great many similarities. Clearly they all belong to the same species, *Homo sapiens*.

But you could not fail to notice certain differences also. For instance, suppose you measure 1000 men for height or for weight. Would these differences in height and weight make a pattern?

THE NORMAL DISTRIBUTION

Scientists have discovered that on the basis of any one trait all animals





11 *These graphs reveal the pattern of the weights and the science marks of the boys and girls of several classes. Where would you fit in each one of the graphs? In each graph where is the largest number of students to be found? the smallest number?*

and plants of any species fall into a definite pattern. You can discover this pattern for yourself by investigating certain traits of the students in several classes in your school. Ask them to give you their weights. You might also have them give you the marks in the last science test they took. What will you find?

The results of measuring weights in several classes in one school is shown in Fig. 11. There were very few students who were of low weight, very few who were very heavy; most were of medium weight. What do you conclude from your examination of the marks on the science test (Fig. 11)? Is your conclusion similar to your conclusion for the measurements on weight? If so, you are correct.

Scientists have found the same kind of results from thousands of investigations of many traits of all animals (including man) and plants. They have concluded that when the traits are plotted on a graph, as in Fig. 11, a *curve of normal distribution* appears. That is to say, a very few of the individuals whose traits we measure are at one extreme (low), another very few are at another extreme (high), but the majority are in between the extremes, that is, in the middle. Now if you think back to your own experiences with people you may find that this is generally true. Most people are not very tall, not very short; they are in between. Most students do not fail in science or in English, neither do most students get 95 to 100 per cent. Most students get marks in between the very high and very low.

THE AVERAGE

Perhaps you would call the "in between" the *average* height, weight, or mark. Most people do. Actually the correct average for weight is found by taking the number of people measured, adding up the weights, and dividing the sum of the weights by the number of people measured. Another way of arriving at an average is to take the highest point in the graphs shown in Fig. 11 for weight and then for science marks. You may know that for any one trait, be it height, weight, color of eyes, color of hair, size of fingers, or intelligence, most people are near the norm, or the average for that trait. But it is wrong to say that a person is an average person. You must always say he is of average height, or of average weight, or of average intelligence. For he may be average or near the norm in one trait, but extreme in another. Do you know anyone who is very short, but of extremely high intelligence? Do you know anyone with average science marks, who is extremely tall? Do you know anyone who is of average height, but is an exceptional athlete? If you have given any thought to these questions, you will see that it is wrong to conclude that because a person is average, or near the norm in many traits, he is average for all. Almost all people have one or more traits which are not average. How do we get these traits we have been talking about?

REASONS FOR LIKENESSES AND DIFFERENCES

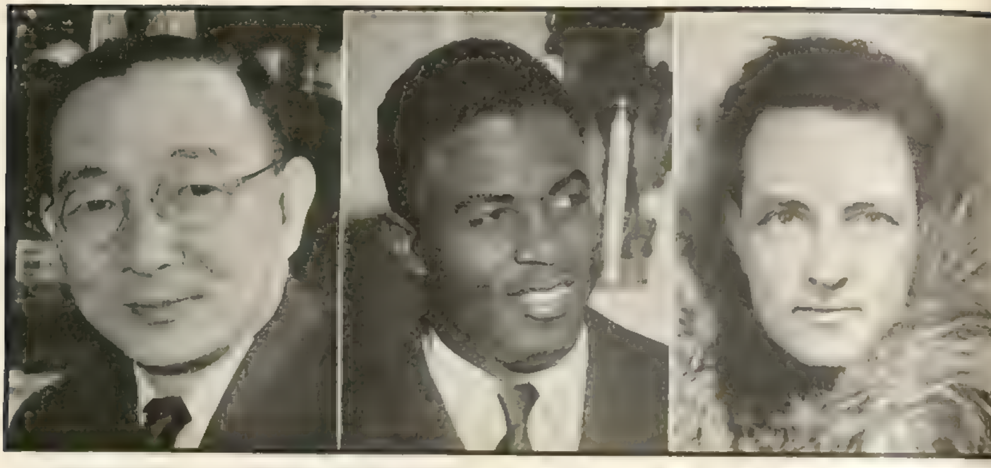
Even with a little thought you realize how we get some of our traits. You know that a hen's egg always produces a chick, not a duck or an eagle. Horses produce their own kind. Lilies produce lilies, not asters or begonias. It's quite obvious that some of our traits are inherited through our parents. For instance, the sheep in Fig. 12 differ in their ability to produce wool. This ability has been inherited through their

12 *Living things may differ in many ways, because of the effect of their environment or their inborn traits. How do these two sheep, similar in size, differ in wool production?* (*U.S. Department of Agriculture*)

parents. But you must be careful to recognize just what scientists mean by inheritance. It is important to distinguish between traits passed on by inheritance or heredity, and those which are produced by the surroundings or environment.

Suppose we were to take the seeds of a variety of corn which normally grows eight feet high. Suppose we plant twenty seeds in rich soil, and twenty seeds in a poor sandy soil. What would you expect to find? The seeds in the rich soil may grow into plants eight feet tall; those in poor soil may be no more than four feet high. Although the seeds were of the same variety, they appear now to have different traits with regard to height. But we know that the difference is due to the soil. If we take some of the seeds produced by stunted plants in the poor soil and plant them in rich soil, the seeds will grow into tall, eight-foot plants. This has been found true for a great number of plants and animals. Plants need good soil (environment) if they are to grow tall (inherited trait). Cows of a breed that produces great quantities of milk (inheritance) need good pasture, good feed (environment) to produce large amounts of milk. Farmers sometimes say that seed (heredity) and feed (environment) make their animals and plants what they are.

The same is true of man. Second-generation Japanese born in the United States are much taller and heavier than their parents. This increase in height and weight is due to the better food and other conditions in the environment. Boys and girls who are educated gener-



13 *These three well-known people are members of different races.* (Left) *Dr. Lin Yutang, a famous author and philosopher, is a member of the Mongoloid race.* (Center) *Jackie Robinson, an outstanding professional athlete, is a member of the Negroid race.* (Right) *Admiral Richard E. Byrd, noted explorer, is a member of the Caucasoid race. All three races have made contributions to American life.* (*Wide World Photos*)

ally do better on the same job than those who are not educated, even if they are of similar inherited intelligence. It is clear that environment and heredity acting together make the individual what he is.

But here is a word of warning. Traits produced by the environment and learned ways are not inherited. Just because you are tanned and muscled from tennis or baseball, your children will not be born with a tan or good muscles. A knowledge of science or of music cannot be inherited. Some traits, you see, are the result of the environment. These learned ways are not inherited, but have to be re-learned by each new generation.

RACES OF MEN

Just as there are certain similarities and differences between any two men so there are similarities and differences between groups of people. Scientists call a group of people which has certain inherited traits in common, a race.

TRAITS WHICH EXIST IN GROUPS

Possibly you have heard of the white, black, and yellow races. Scientists have discovered it is impossible to divide men into groups solely by the color of their skins or any other single characteristic. The shape of the head, the color and texture of the hair, and the shape of the nose are some of the characteristics used with skin color to determine the races to which men belong. For instance, the Hindus, who belong to the so-called "white" race, generally have brown or black skins. But other characteristics such as those listed in Table II place them in the white race, or the Caucasoid (kô′kȧ soid) race, as scientists prefer to call it.

Scientists have grouped all living men in one species, *Homo sapiens*, and they have divided the one species into

Table II. MAIN RACES OF MAN

Races and subraces	Texture of hair of head	Hair of body and face	Head	Nose	Protrusion of jaw	Skin color	Stature
CAUCASOID or "WHITE"							
Nordic	wavy, blond	abundant	narrow	narrow	slight	very white	tall
Alpine	wavy, blond	abundant	broad	narrow	slight	white	above average
Mediterranean	wavy, dark	abundant	narrow	narrow	slight	dark white	medium
Hindu	wavy, dark	abundant	narrow	variable	moderate	brown	above average
MONGOLOID or "YELLOW"							
Mongolian	straight, dark	slight	broad	medium	medium	light brown	below average
Malay	straight, dark	slight	broad	medium	medium	brown	below average
American Indian	straight, dark	slight	variable	medium	medium	red brown	tall to medium
NEGROID or "BLACK"							
Negro	woolly, dark	slight	narrow	broad	strong	black	tall
Dwarf Black	woolly, dark	slight	broad	broad	moderate	black	very short
Melanesian	woolly, dark	slight	narrow	broad	strong	black	medium

Adapted from A. L. Kroeber, *Anthropology*, rev. ed., Harcourt, Brace, 1948, Fig. 6, p. 132.

three main races (Fig. 13). These are the Caucasoid, Mongoloid (mŏng′gŏl-oid), and the Negroid (nē′groid). Each race is further divided into subraces.

Although many unthinking people believe that the Caucasoid race is made up of white people, there are in fact white-, brown-, and black-skinned people in the Caucasoid race. The majority are light-skinned, tall, with oval heads, noses with narrow bridges, and a good deal of body hair. In Table II you will find summarized these and other characteristics of the Caucasoids. Some scientists divide the Caucasoids into several subraces among which are the Nordic, Alpine, Mediterranean, and Hindu subraces.

The Mongoloids are people who have high cheekbones, broad faces, medium sized noses, and eyes which appear to be slanted. Actually their eyes are not slanted; there is a skin fold above the eye which falls over part of the eye and gives it its slanted appearance. The Mongoloids are subdivided into these main subraces: Mongolian (most Chinese and Japanese), Malay, and American Indian.

In the Negroid race are grouped all people with dark skins, narrow heads, broad noses, small amount of body hair and other characteristics which you will find in Table II. You will also find the Negroid subraces, Negro, Melanesian, and Dwarf Black. The Melanesian subrace is found in New Guinea, the Philippines, and other Pacific islands.

You may wonder why we have listed these races. We have done so for two main reasons. First, we believe you should know the scientific basis for grouping people into races. Although the three races differ from each other, scientists also know that these differences are small compared with the

similarities that all races share. All men in all races have the ability to learn. As a matter of fact, if we were to use 1000 pages to list the similarities and differences among the races of men, we might use about 999 pages to list the physical similarities and one page to list the differences.

Our second reason for presenting the scientists' definition of race is to give you a dependable basis for making decisions about abilities of all people. People who do not know that all races share the great human qualities sometimes make untrue statements. Some may claim that one race is superior to another. Such statements have been made to divide people, to set them against each other. Adolf Hitler, for example, claimed the white race to be superior. Hitler went even further. He told the German people that people of German blood were superior to all others. What facts have scientists discovered about the superiority or inferiority of races?

WHOSE BODY STRUCTURE IS MOST PRIMITIVE?

Anthropologists (ăn′thrô pŏl′ô jĭsts), scientists who study man, define a primitive characteristic as one which may be found in the earliest or most primitive man.

Since primitive man is thought to have had a hairy body, some anthropologists place hairiness of body and face as a primitive trait. Lack of hair is thought to be a trait of people far advanced from primitive man. In this case, the Caucasoids must be considered most primitive since their bodies have the most hair. On the other hand, the Mongoloids are most advanced; they have the least body hair.

When we consider the kind of hair, straight hair is thought to be the most primitive, curly hair next, and woolly hair the most advanced. On the basis of kind of hair, the Mongoloids are the most primitive, but the Negroids are most advanced. Now if we take the broad nose as primitive, the Negroids become most primitive, the Mongoloids come next, while the Caucasoids are the most advanced.

You can see on the basis of this kind of comparison that first one then another race falls into the primitive or advanced class. Scientists are forced to conclude that on the basis of a study of many characteristics and body form no one race is more primitive or advanced than the other.

WHOSE INTELLIGENCE IS HIGHEST?

No doubt you have taken one or more intelligence tests sometime during your schooling. Scientists are now convinced that these tests do not test inborn intelligence or inborn problem-solving abilities alone but also test the influence of the environment on the people tested. An example will make this clear.

When intelligence tests were given to white and Filipino children living in the Philippines, the white children scored higher. The tests were written in English, which both groups of children understood. On the other hand, when the tests were written in the Filipino language which both white and Filipino children also understood, the Filipino children scored higher. Obviously the language spoken in the children's homes influenced the scores in the intelligence tests.

Recently it has been clearly shown that the scores of children on intelligence tests can be raised if the children are first trained to understand the kind of language in which the test is written; that is, the language and forms of intelligence tests. Furthermore, it has been found that Southern Negroes who

move North raise their scores on intelligence tests after the first year.

In order scientifically to compare intelligence of different racial groups, the groups tested must have similar environments and similar opportunities for education. With this in mind scientists are in agreement that as yet there is no evidence that any race is superior in intelligence to any other.

ARE THERE SUPERIOR RACES OR NATIONALITIES?

The evidence is overwhelming that given the same kind of environment, the same kind of opportunity, no race as a group is superior to another.

Those who hold to the theory of the superiority of races generally compare the best in one race with the poorest in the other. Surely a person of one race living in a fine neighborhood may show certain traits which will be superior to those of a person of another race living in a slum area. It isn't good thinking to compare the best in one race with the worst in others. Caucasoid, Negroid, and Mongoloid—all races have their scientists, artists, musicians, and leaders in other fields.

Some people confuse race with nationality. A nation may consist of many races. Thus the United States has citizens who are Mongoloids, Negroids, and Caucasoids. All of them are Americans. France has a nation composed of the three main races; all of them are Frenchmen. England has many racial types and so have many other nations. There is no evidence that one nation is superior to another if the people composing both nations are given similar environments and opportunities. The people of different nations differ in their customs, which are learned, but not in their native ability, which is inborn.

A POINT OF VIEW ABOUT RACES

If the facts clearly indicate that there is no superior race, that all men have contributed to civilization, why do people of one race consider themselves superior to all others? There is good evidence that this feeling is nothing but prejudice. Prejudice means holding a belief not based on fact. You should try to root out prejudice and become a responsible, reasonable person. Here are three suggestions.

1. Live by the evidence. The evidence shows that no race or group is superior to another.

2. Be clear in your thinking. Compare the best in one race with the best in another. In comparing people, make allowances for differences in environment and in opportunities.

3. Be democratic. Give everyone the same treatment you would want for yourself. Give everyone a chance to live a dignified decent life.

If these patterns of behavior become part of everyone's makeup, race prejudice may soon be eradicated. You see that race prejudice is a problem for every person. The scientist has made available the evidence that no race has special vices or virtues. But it is you who will use the evidence to live in peace with your neighbors.

ASCENT OF MAN

This chapter has taken you through a rapid survey of your own beginnings. What a remarkable past you have! You go back about a million years. You are a member of the most capable species now living—*Homo sapiens*. Your species is distributed all over the earth. Wherever you go, you find people like yourself who have become what they are because of their heredity and environment. Your brain, your speech apparatus, your hands are the tools

with which you and some two billion human beings like you can fashion a secure and happy life on this earth.

GOING FURTHER

1 *Placing yourself.* Where do you "fit" in your class? With the help of your teacher organize a committee which will study the distribution of the students in your freshman high school class as far as the characteristics of height, weight, color of eyes, and color of hair are concerned. For eye and hair color, put the students in your freshman class in three groups—light, medium, dark. For weight and height, graph boys and girls separately.

2 *How to get a free copy of this book.* Go on a search for two things which are *exactly* alike. You may measure peas from the same pod, leaves from the same tree, twins, two different parts of your own skin. We state now that you will not find two living things exactly alike. If you do and can prove it to the authors of this book, we shall send you a free copy.

3 "*Making*" *a fossil.* You can make an imprint or cast of a fossil in this way. Take plaster of Paris and mix it with water till it forms a thick paste. Now place a clamshell, or a leaf, or similar object on the moist plaster. Pour some more wet plaster on the leaf or clamshell. After the plaster has dried, break it open with a few gentle taps of a hammer. Remove the leaf or clamshell. You will have a cast of the remains of a living thing. Many fossils were formed this way, except that soil or sediment (not plaster of Paris) carried by water enclosed the animal or plant remains.

4 *Words are ideas.* Here are the key words to the big ideas in this chapter. Can you use each of them in a sentence which will give its meaning? Use the glossary.

fossil	Mongoloid	extreme	Neanderthal
race	Negroid	curve of normal distribution	Java man
prehistoric	Caucasoid		nationality
average	Cro-Magnon		

5 *Put on your thinking cap.*

1. "Oh, he's just an average person in everything he does," said Mr. Doe. Having overheard Mr. Doe make this common statement, what would you say to him?

2. "Man's brain will help him solve all his problems," said Mr. Sureitso. What are some of the important problems man has left unsolved?

6 *Test yourself.* In your notebook, match the left column against the right by bringing together correctly the numbers of the left column with the letters of the corresponding phrases on the right. Do not mark this book.

1. fossil	A. first manlike fossil
2. norm	B. prehistoric remains of living things
3. Java man	C. prehistoric reptiles
4. dinosaurs	D. a race of man
5. Rancho de la Brea	E. a fossil nearest to us in structure
6. Cro-Magnon man	F. the highest point in the curve of normal distribution
7. Mongoloid	G. a source of fossils

7 *Adding to your library.*

1. *Animals of the Past* by A. F. Lucas, American Museum of Natural History, New York City. This is one of a series of pamphlets that is an interesting, well-illustrated account of life of the past.

2. Write to the Curator of Education at either the Chicago Field Museum, Chicago, Illinois or the American Museum of Natural History, New York City, for a list of pamphlets on prehistoric life. For instance, there are booklets on ancient men and ancient plants as well as on ancient animals.

3. *Race Differences* by Otto Klineberg, Harper, 1935. Although this book has many words that will be new to you, it is a good source book for facts about races. A good dictionary will help you read this book.

CHAPTER 2

MAN—MASTER THROUGH LEARNING

Here you sit reading this sentence. There is nothing strange in that, you may think. Yet do you realize that no creature but man can do this?

It is true that Sir John Lubbock had a dog who was trained to eat or drink when he saw a sign EAT or DRINK. As you will learn later from some of Dr. Pavlov's interesting experiments, dogs can learn. By experimenting with animals we learn something about learning. The last word in the preceding sentence—*learning*—is the key. You and all other men owe much of what you are to the capacity for learning. True, this capacity is present in a limited way in other animals. But man is distinguished from other animals mainly by his ability to learn so much more.

Your success in life depends in large part on your ability to learn. You need to learn well to do a job well. You need to learn to get along with others. You need to learn how to learn well.

In order to understand the basis of learning you will need first to know about the part of your body which is responsible for learning, namely, your nervous system. After that you will be able to understand how learning has helped change your personality and how it will affect your future.

THE SENSE ORGANS

You probably know that you recognize your surroundings through your sense organs. These sense organs are said to receive *stimuli* (singular *stimulus*) from the environment. A stimulus is anything in the environment to which plants or animals react. Light and sound are two kinds of stimuli. Any reaction to a stimulus is called a *response*. Your getting up to the sound (stimulus) of your name is a response.

No doubt you have realized that you are never free from stimuli. Light waves are reaching your eye, and sound waves are reaching your ear now. You can see why the eye and ear are called *sense organs*. They receive, or sense, the stimuli of light and sound.

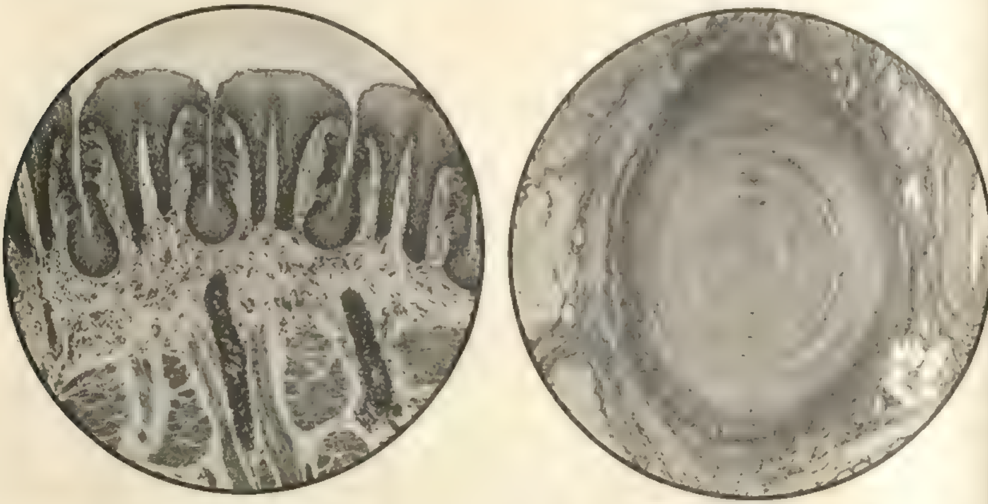
Touch your knee. Touch your head, your elbow, your cheek, your hand, your toe—any part of your body. You feel the touch. You are stimulating the sense organs in your skin. These sense organs are sensitive to pressure (Fig. 14). There are also sense organs of pres-

sure and pain in other parts of your body. Thus you may feel a stomachache. The sense organs inside your body warn you that your internal organs are not working right. Whether you are awake or asleep, your sense organs are constantly being stimulated.

Next time you eat, ask yourself, "How do I taste my food?" You will recognize that there must be sense organs in your mouth. Actually sense organs for taste are found in your tongue (Fig. 14). As you smell food, you will recognize that your nose has the sense organs which detect odors.

These then are your chief senses: sight, hearing, taste, smell, and touch (feeling objects, feeling changes in temperature). With these sense organs, we maintain contact with our environment. With them we recognize our friends, our homes, danger, or safety.

Let us see how stimuli received by your sense organs lead to responses.



14 (Left) *A magnified view of a microscopic portion of a tongue. The raised portions are taste buds.* (Right) *A magnified view of a type of nerve ending which senses pressure. These microscopic bodies are sensitive to touch and are found at the tips of your fingers.* (*General Biological Supply House*)

THE BASIS OF ALL BEHAVIOR—THE NERVOUS SYSTEM

Let us turn to a frog for our study of the nervous system. Suppose we dissect a preserved frog. Once we get past the skin, and push aside the intestines, we see long shiny threadlike structures along the backbone. These are the *nerves*. As we look, we find these nerves everywhere leading to arms and legs, to all parts of the frog's body much as they do in yours (Fig. 15). Where do they come from or lead to?

By patiently tracing these nerves we see that all of them come from or lead to the long spinal column and the bony brain box.

When you look at Fig. 18 you will see the plan of the human nervous system. Nerves lead from the spinal cord or from the brain to and from each part of the body. The brain and spinal cord seem to be the centers of this system of nerves.

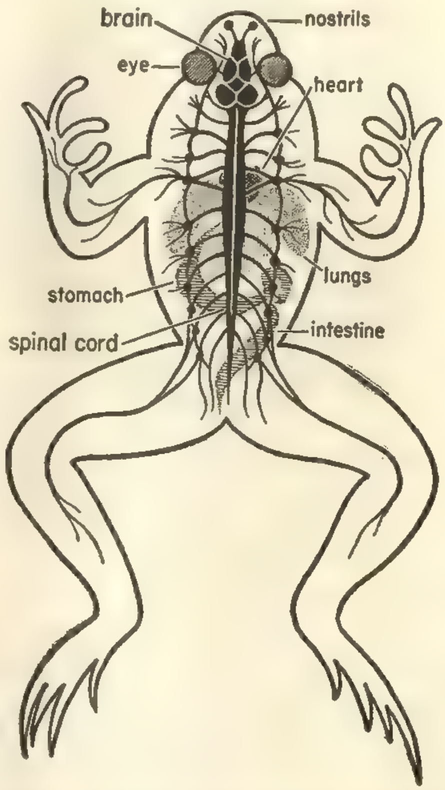
NERVES AND NERVE TISSUE

Let us take a bit of brain or spinal cord of an animal and examine it carefully under the microscope. The bit of brain is prepared for examination by specially trained people who cut it into very thin slices and then stain it. When we look through the microscope at the tissue, we see a number of *nerve cells* and the fibers which lead from them (Fig. 16). If we were to examine any part of a plant or animal body, we would find cells of different shapes. Each one is microscopic in size. But it is these microscopic cells, as you may remember from your earlier work in science, which are responsible for all the functions of your body. At present, it is enough to know that the nerve cells with their fibers are responsible for the functioning of the nervous system.

When we study one nerve cell, we see that it has a long fiber (the axon) at one end, and short fibers at the other. It looks like the one in Fig. 17. No matter what part of the nervous system we examine, we find these cells or their fibers. What happens when a nerve reacts to a stimulus is not entirely known, but scientists call whatever travels from one nerve to another an *impulse*. The nerve cells send impulses to each other by means of the fibers at their ends, which do not actually make contact but are very near each other.

This fact may give you a hint that will help to explain why the parts of the body work together. If all these nerve cells connect with each other then that may be the way one part of the body is co-ordinated with another. There are billions of connections so that a stimulus from any part of the body can affect any other part of it. In the spinal cord and brain, the nerve cells connect with each other by their connecting fibers. Outside of the spinal cord and brain, the axons, grouped together, form nerves. Each nerve is made up of thousands of nerve fibers together in a bundle, much as a cable is made up of separate wires.

Many experiments have shown that the brain is the center of feeling and understanding. Modern surgery is based

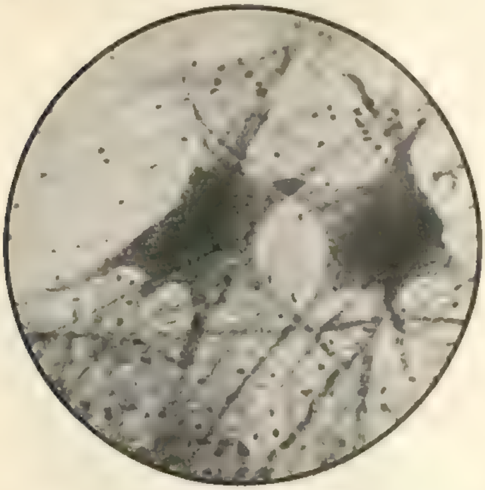


15 *A simplified diagram of the nervous system of the frog. Notice how the nerves go to the different parts of the body. Can you distinguish the brain from the spinal cord and its nerves?*

on the knowledge that the nerve cells in the brain can be "put to sleep" with ether or other anesthetics. Then the brain doesn't feel any impulses from the part being operated on. Sometimes the nerve cells near the point being treated

may be deadened by novocain, as when your dentist pulls a tooth. What the novocain does is to prevent the impulses from getting to the brain from the nerve in the tooth.

Look at the system of nerves in the human body (Fig. 18). There are nerves to every part of the body.



16 *A view under the microscope of two nerve cells. Do you see the fibers which extend from each cell? (General Biological Supply House)*

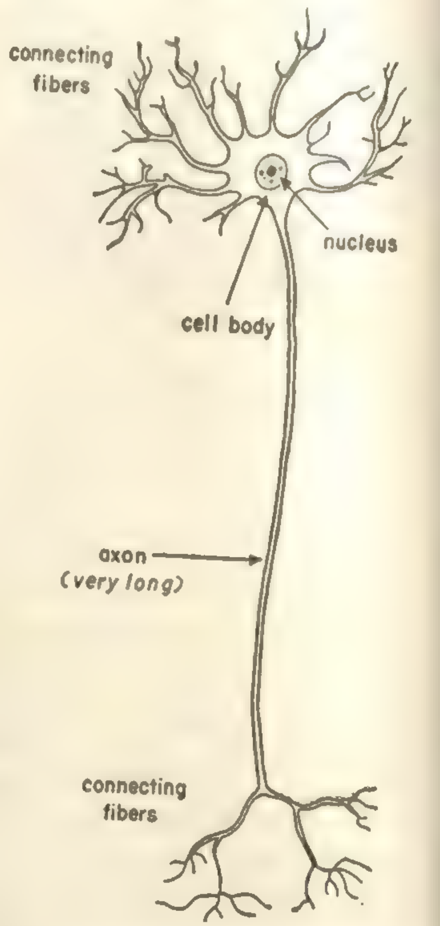
THE BRAIN CENTER

Our nervous systems are truly amazing things. Here is a friend writing the chemical formula for water (H_2O), hydrochloric acid (HCl), and of potassium chlorate ($KClO_3$). Here is a student solving a problem in algebra; he finds that since $x^2 = 16$, $x = 4$. Another student is memorizing Lincoln's Gettysburg Address. And here you are reading the printed word and learning about the nervous system. A dog or a chimpanzee cannot do any of these things; but man can do all of them.

No scientist knows exactly how the nervous system does its work. There are many experiments which indicate that the nerves carry impulses to the brain. We know, too, that somehow the brain interprets and reshuffles these impulses so that they go to the right place.

As Fig. 19 shows, we can see also that the brain is made up of three parts. The *cerebrum* (sĕr′ē brŭm) sits like a cap on the *cerebellum* (sĕr′ē bĕl′ŭm). And the *medulla* (mē dŭl′ȧ) is that long portion which connects with the spinal cord.

We know that the cerebrum has certain areas in it which specialize in certain functions. For instance, from various experiments with animals, and



17 *A diagram of a common type of nerve cell. How is it fitted to carry impulses and to connect with other nerve cells?*

from a study of accidental injuries to the human brain, scientists have discovered that the area for thought, memory, and feeling is located in the front part of the cerebrum. The area for hearing is located at the side of the cerebrum, and that for sight in the rear. Because scientists know the function of each part of the cerebrum, they have been able to make a map which shows the location of the part of the cerebrum which controls each function (Fig. 20).

The cerebellum is the center for co-ordination of the muscles. Your ability to co-ordinate all your muscles in walking, or your muscular co-ordination in kicking a football, dancing, writing, threading a needle is centered in your cerebellum. Your medulla is the center of certain of your most important acts: breathing, heartbeat, and others like swallowing and yawning. The medulla helps to control the vital acts (breathing, heartbeat) on which life itself depends.

INBORN WAYS OF BEHAVIOR

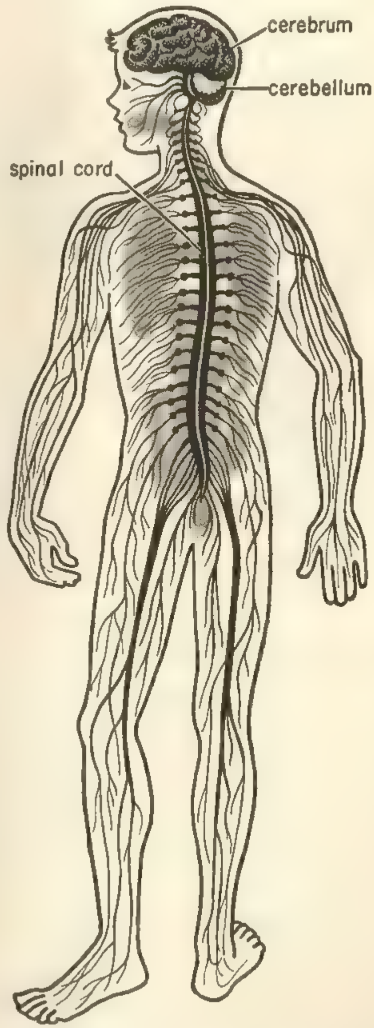
At the moment you were born, you could do certain things with some perfection. These acts were practically perfect without practice. Some simple experiments will show you the acts you can perform without practice.

UNLEARNED BEHAVIOR

Get a piece of glass or cellophane which you can hold before your face. Now ask a friend to throw balls of paper at the glass. We predict that you will blink your eyelids. Try it. Then try it on your friend, and on others.

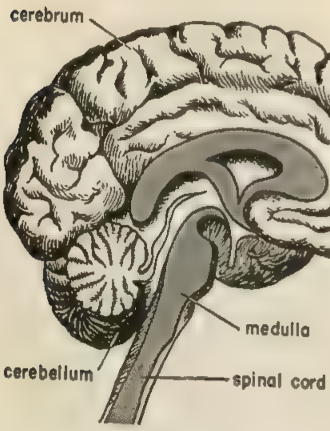
Here is another experiment. Stand before a mirror, searchlight in hand. Look into the mirror. Then flash the searchlight at one eye. We predict that your pupil will become smaller. Try it on other students. Is it true of their pupils also?

Without knowing you personally, we know that if you are tapped just below the kneecap, your foot will kick out.



18 *A diagram of your nervous system. What cannot be shown is that nerve endings go to the cells of your body. Trace a stimulus at the finger tips to the cerebrum. Where would you locate the medulla?*

Without seeing you we know that your ribs and diaphragm are moving as you breathe. We also know your heart is beating. Furthermore, we know you cannot control these acts. Try to control your heartbeat. Try to stop your breathing for more than a minute or so.



19 *A diagram of the brain cut through the middle. What are the functions of the cerebrum? the cerebellum? the medulla?*

INBORN AUTOMATIC ACTS

All these acts are *reflex* acts. Like all other responses, reflex acts occur only when there is some stimulus to produce them. The nerve pathways along which the impulses travel are inborn, however. Practically every human being has the same reflexes.

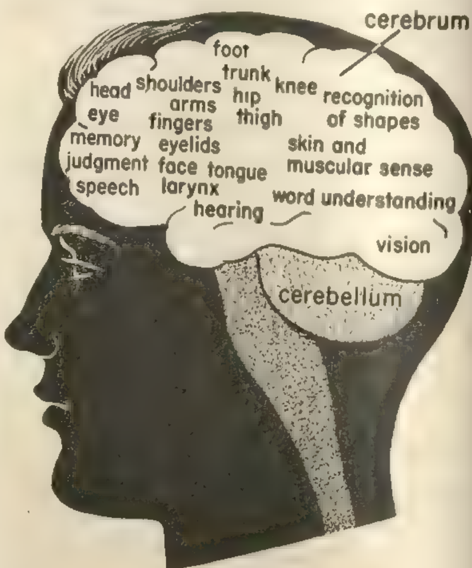
Light shining on the eye is the stimulus for the automatic reflex action of the muscle that controls the size of your pupil. A quick movement before the eyes is one stimulus for the automatic blinking response. Dryness of the eye is another stimulus that produces blinking. There is a stimulus for every reflex act, even for your breathing, for your heartbeat.

USEFULNESS OF REFLEXES

Try this. What is $8 \times 16 \div 2 \times 4$? Ah, you have to think about it. Suppose you had to think about getting your heart to beat, your lungs to breathe, your stomach to digest, your eyelids to blink, your pupils to become smaller in bright light. Not only that, but suppose you had to think about keeping your heart, lungs, stomach, and intestines working regularly and in rhythm as they do now. Impossible! Of course. Because these acts are reflexes, they are automatic. Thus your heart beats, you breathe, and you digest your food automatically.

EXPLAINING THE REFLEX ACT

Now that you have an idea of the structure of your nervous system, let us analyze a few of your common actions, or behavior patterns.

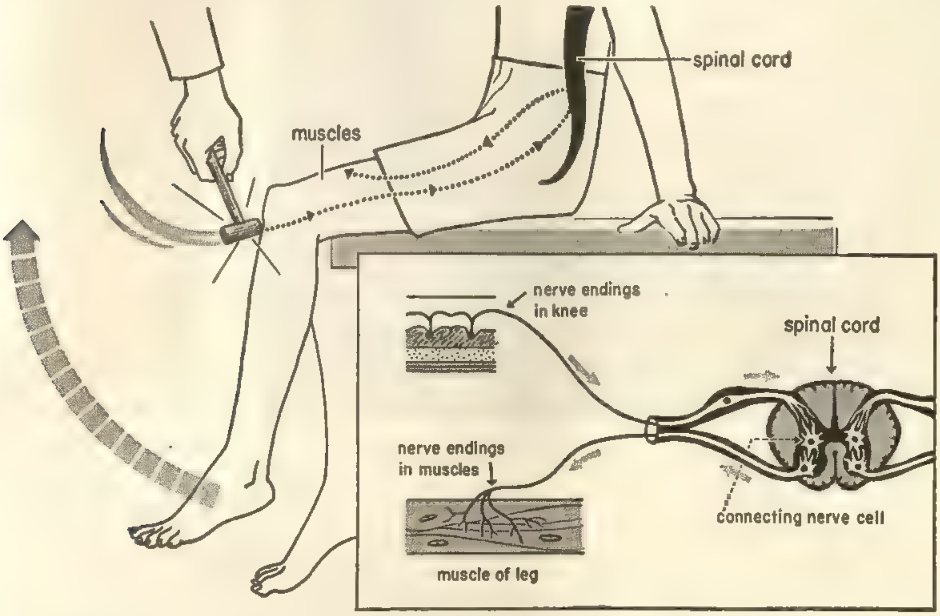


20
Diagram of the functions of your brain. Which parts of the brain are you using now?

SIMPLE REFLEXES

First, let us analyze a common behavior pattern like your knee reflex. The stimulus, a blow below the kneecap, sends an impulse along a nerve. This nerve takes the impulse to the spinal cord. From here it is returned to the leg muscle. A diagram of the reflex nerve pathway looks like the one in Fig. 21. You are born with this and other reflex nerve pathways like those for blinking and sneezing.

A reflex act may take place even if the person is under ether and the cerebrum is therefore not acting. Reflex acts do not need thinking. This helps explain a rather peculiar thing. Picture this. You touch a hot iron with your finger. Quickly your arm muscles draw your finger away. After you have withdrawn your finger, you say, "Ouch." Withdrawing the finger from a hot object is a reflex act. The impulse doesn't travel to the brain. The impulse travels first to the spinal cord, then immediately back to the muscle. Withdrawing your finger from the hot object happens, therefore, without thinking. But saying "ouch" needs thought. It is a response you have learned. Since you said "ouch" after you pulled your finger away, it indicates that your brain was not involved in the act of removing the finger.



21 *Diagram of a reflex act. Have you ever had your knee reflex tested by a doctor? Try it at home. Follow the path of the impulse as it goes from the nerve endings in the knee to the spinal cord and then to the muscles.*

However, much remains to be explained. Even though we do not know just what an impulse is, or how thinking is carried on, we know that nerve cells are responsible for these acts. We know that reflexes are inborn automatic acts whose nerve pathway is present at birth. Once the stimulus is given, the impulse travels over this pathway and the response occurs.

22

A robin on its nest. Birds do not have to learn to build nests. Nest building is an instinct. (U.S. Fish and Wildlife Service)

SERIES OF REFLEXES

But not all inborn (inherited) automatic acts are as simple as reflexes. Have you ever watched birds building a nest? Or a spider spinning its web? None of these animals needs to learn how to build a nest even though nest building is a complicated process. Actually all birds of the same kind build much the same kind of nest. If you learn to recognize one robin's nest, you will recognize the others. Each robin builds the same kind of nest, a bowl-like structure, with the same kind of materials (Fig. 22). Such inborn automatic acts like nest building are not simple reflexes, however. Scientists call such acts *instincts*.

Instincts are more complex than reflexes. For instance, watch a digger wasp build its nest. First, it stings a caterpillar; then it digs a hole. Then it drags the caterpillar in, lays its egg on it and closes the hole. Intelligent? Clever? Purposeful?

Let us see. Scientists have experimented with wasps. After a wasp has dug its hole, has dropped the caterpillar into it, and has begun to close the hole with dirt, another caterpillar is put near its nest. The wasp pounces on this fresh caterpillar, digs a new hole and lays an egg on it. She closes this hole as before. Now she has no more eggs. Another caterpillar is placed near her nest. Again she does the same thing even though she has no more eggs. This can be repeated any number of times.

The caterpillar is the stimulus for the response "digging the hole." Each time the stimulus is given, the wasp makes the same automatic response. We have called this simple response a reflex. Scientists have shown that the whole instinctive act in the wasp—nest making and egg laying—is a series of reflexes. One reflex act precedes the other and acts as a stimulus for the next reflex. An instinct is like the reflex; it is an inborn automatic act.

HUMAN "INSTINCTS"

You have heard people say, "Instinctively, I disliked him." Let us analyze this statement. Instincts are inborn and automatic. They are a series of reflexes, and one reflex sets off another. Now, is the body born with an "instinct" to dislike any particular person? Of course not. We need to meet a person before we know whether we will like him or not. Most kinds of behavior which we acquire after birth (such as the behavior just described) are learned.

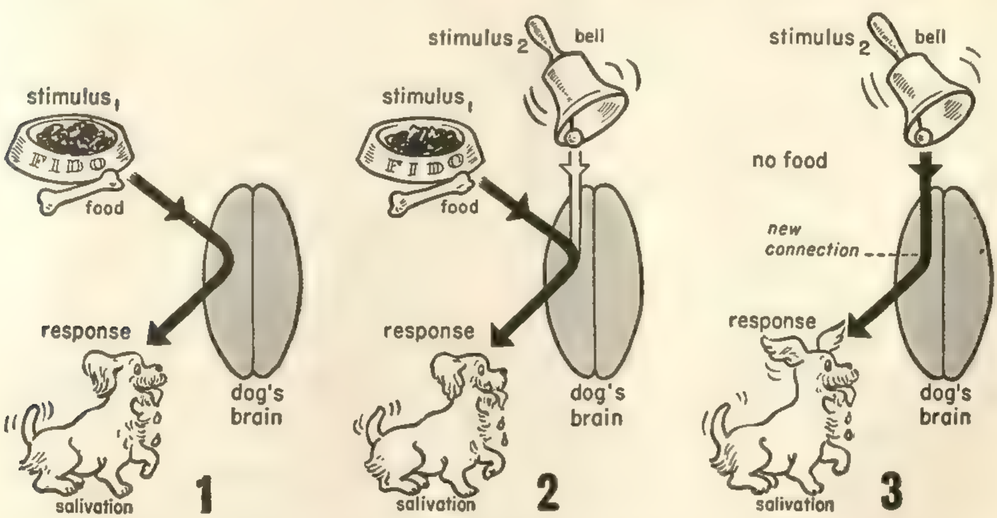
CHANGING INBORN BEHAVIOR

As you might expect, many scientists have been studying learning. The ability to learn has a good deal to do with determining whether man will be successful in getting even greater control over his environment. If scientists could determine how learning takes place, what happens in our nervous systems as we learn, we would be a long way on the road toward solving many of the important problems which trouble mankind. Ivan Pavlov (ē vän′ päv′lôf) was one of the first to do some important experiments on learning. And this is what you might have seen had you visited him early in this century.

PAVLOV'S DOGS

In Ivan Pavlov's laboratory in Russia, you would have seen a dog acting very strangely indeed. The moment a bell was rung, the dog began to salivate. (Saliva flowed in his mouth, much as it does in yours when you see or smell a very inviting meal.) He acted just as if he were going to be fed. Normally, a dog's mouth doesn't water when he hears a bell. This response must have been acquired or learned. In fact, some of Pavlov's dogs would salivate at the sound of a bell, others at the lowering of a white square or a flash of light. How did they acquire this behavior?

Pavlov knew that every time a dog saw food he salivated. Pavlov first rang a bell, then he gave the dog food. In



23 *A diagram of conditioning. Why does the dog eventually respond to the ringing of the bell?*

other words, the dog was presented with two stimuli at once, food and the sound of a bell. After a few weeks, when the bell alone was rung in the absence of food, the dog responded to the bell as if he were responding to food. He salivated. Apparently a substitute stimulus, the sound of the bell, now had the same effect as the original stimulus, the smell or sight of food (Fig. 23).

In the nervous system, connections had been made between nerve cells so that the salivating response was given not only to the sight and smell of food but also to a new stimulus (Fig. 23). The dog's inherited behavior had been changed.

In much the same way, a dog learns to give a new response to an old stimulus. For instance, hunting dogs on farms sometimes hunt and kill chickens. How would you train the dog to leave chickens alone? Some farmers tie a chicken which the dog has killed around his neck with wire. Soon the chicken begins to decay and smell with a very foul odor. In the dog's nervous system, the stimulus "chicken" may be associated with the stimulus "foul odor." Or the stimulus "chicken" may have become associated with the stimulus "harsh words" given by the dog's master. Thus, the dog is trained, and learns to leave chickens alone.

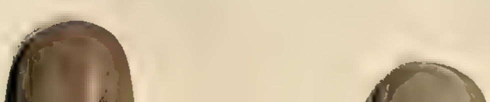
THE CONDITIONED REFLEX

The act of salivation is a reflex. The stimulus, food, causes an impulse to travel along an inborn nerve pathway. The substitute stimulus, the ringing of the bell, is given simultaneously with the old stimulus (Fig. 23). In this way it is associated or connected with the inborn nerve pathway. For a period of time, the new stimulus is given with the old, the two are connected, and produce the same response. Eventually, the new stimulus alone produces the desired response (Fig. 23). It is as if the animal had acquired a new reflex. Pavlov called this acquired reflex a *conditioned reflex.*

Notice the part that reward and punishment played in this formation of a conditioned reflex. Each time Pavlov's dog heard the bell, he also received food which he liked (reward). Each time our farmer's dog saw the chicken tied to his neck, he smelled a foul odor which he disliked (punishment). Pavlov found that after his dogs had learned to salivate on hearing a bell, he could break the conditioned reflex. He did it this way. When the bell was rung, the dog salivated. But he was not given food (his reward). This was repeated each time the dog reacted to the bell. After a while, the dog no longer salivated on hearing the bell. His conditioned reflex had been broken. Later you will learn how a reward or punishment given at the proper time may be of use to you in learning.

TRAINING YOUR DOG

You can use Pavlov's conditioned reflex to teach your dog different kinds of behavior. Suppose you want your dog to learn to sit up. Each time you give him his food or something he likes, say, "Sit up" and make the dog sit up. The stimulus, food, and the sound of the words "sit up" (and the position of his body) will be associated in the nervous system. Soon the dog will sit up when you say, "Sit up." Be sure when he does this to reward him, pet him, or give him something he likes. You needn't do it each time, but do it often enough so that the learned behavior is fixed; that is, make sure that the stimulus and response have been associated in the nervous system through conditioning.



TRAINING CHILDREN

In much the same way a very important kind of behavior in you was formed by training or conditioning. We are speaking of the habits you acquired at an early age. A *habit* is a learned automatic act. Note that a habit is unlike a reflex in that a reflex is an inborn automatic act.

Suppose you were to look at your watch and find that it was twelve o'clock. Probably you would say, "Time for lunch." How did breakfast, lunch, or dinner become associated with a particular time?

When you were young, very, very young, you were fed your lunch at about twelve o'clock. The nerve pathways for feeding and the nerve pathways used to tell time became associated. Why? Every day you were fed at the same time. There were few, if any, exceptions.

Suppose later on when you were five or six years of age, you did not come to lunch when you were called, or did not come to lunch on time. Well then, several things may have happened.

1. You did not get any lunch.
2. You were spanked.
3. You were punished in some other way. Perhaps you did not get the dessert you liked, or you were deprived of some expected pleasure.

On the other hand, when you were on time your reward was your parent's affection. You received the things which any boy or girl in your position might expect to get. Thus a reward or a punishment helped to fix the habit.

FORMING HABITS

You can appreciate the importance of habits in your daily living. You get up in the morning. You wash, dress, tie your shoelaces, knot your tie. You brush your teeth. You use a spoon and fork. You switch on the radio to hear the morning weather report. You assemble your books. All these are habits, or a series of habits. They are nerve pathways developed since birth.

Do you want proof? Watch your baby brother or sister, or any baby (Fig. 24). Can it do the simple things we have mentioned above? See how long it takes before the baby forms the habit of holding a spoon correctly, or of holding a toothbrush properly.

If you had to figure out how to do these things every morning, it might take all day. Good habits, therefore, save time. Such habits make life more efficient. Habits are acquired automatic acts. By acquiring new habits, you are able to change your behavior. Bad habits waste time and may result in failure in your work. Good habits improve your behavior, and make for success.

CONTROLLING HABIT FORMATION

Now that you are older, the responsibility for forming new habits, habits that will make life easier to live, depends upon you. The baby's muscles and nervous system were not developed sufficiently to deal with the things and the people in its environment. It could not meet new situations without help and training. To a great degree, you can meet new situations and form new habits.

At first everyone needs help in forming habits. As we grow up, we take more and more responsibility for our own actions. In order to form a habit at your age, you should first want to form that habit. Although conditioning (habit formation) may go on whether we know it or not, it is generally agreed that habits are formed most rapidly

when there is a desire to form the habit. Second, you must plan and practice the routine regularly. Also, getting satisfaction out of it helps fix the habit.

Let us take an example. You notice that your friend rides a bicycle. "How nice if I could ride one," you say. So you decide to take lessons. Good! You are on your way. You want to form the new habits, the new pathways in the nervous system that will enable you to ride a bicycle.

Step 1. First, you will have to form the habits which will be useful in getting on the bicycle, balancing yourself, and driving the machine forward.

Step 2. In order to ride the bicycle well, you find that you need to practice. You do; you arrange your time so you can practice such things as getting on the bicycle with the left foot from the left side. In practicing you try not to practice the wrong acts. You do not repeat your mistakes, only the correct acts. Again, good. This is the second step in forming a habit. You should regularly practice the act correctly so as to establish the new nerve pathways quickly and effectively.

Of course, when you first ride the bicycle for a block or so you get a good deal of satisfaction. As a result you practice more. You become skillful in bicycling. You get considerable satisfaction out of performing the act. Satisfaction helps fix the pathways in your nervous system and you now have made the new habits a part of you.

HABIT FORMATION EQUALS LEARNING

"That's not habit formation, that's learning," you say. "I learned to ride the bicycle." Habit formation and learning are very similar. To learn is really to acquire new methods of responding to stimuli. In order to learn efficiently, that is, to acquire rapidly new ways of responding to stimuli and to form new pathways in your nervous system, you should follow these rules of habit formation.

1. You should want to learn.

2. You should plan your work. You must practice the correct act regularly.

Successful learning brings satisfaction. This in turn encourages you to practice more until the habit is fixed.

Do you want to learn how to play basketball, how to dance, how to read well, or ice-skate? Then reread one and two above and apply them to learning.

GETTING RID OF POOR HABITS

If new ways of behavior, or habits, can be learned, they can also be unlearned. You know how quickly you forget something learned if you don't use it—or practice it. Of course, you can regain much of your skill in it if you practice again, or review your work. That is true of baseball or ping-pong, or knitting, or reading, or speaking.

But let us suppose you have a poor or undesirable habit. What is a poor habit? It is an acquired act which may make people lose their respect for you, or one which wastes your time, or one which may result in poor health.

In order to break a bad habit, you substitute a good one. In order to do this, you should:

1. Have a strong desire to break the habit.

2. Analyze the reasons why you practice the bad habit.

3. Practice a more desirable activity in its place.

Here again you can see how you differ from other animals. You can change your behavior by getting new habits or changing old ones. Let us

apply this information and see how to break the "tantrum" habit.

CONTROLLING THE EMOTIONS

Some boys and girls have the habit of becoming emotional when things do not please them. For instance, if they do not get a thing they want, they sulk, or shout, or cry, or refuse to eat, or go into a tantrum. In any event, their reaction isn't the reasonable response that a thinking person would give.

Of course, we don't mean to include the "up" and "down" feelings every boy and girl your age may have. That is perfectly normal. Everyone has his ups and downs emotionally. For instance, one day you may be feeling very good. Everything is wonderful; you are optimistic. The next week, or day, you will be feeling gloomy; you are pessimistic. Then, at times, you may may feel "in between" these moods. This is normal. The only thing to remember is not to make any important decisions when you are feeling exhilarated or gloomy.

However, we are dealing here with the type of behavior that no one likes —the tantrum. When a baby yells or cries, he gets attention. If the baby's parents give him what he wants each time he yells or cries, this behavior may become a habit. Later on he may yell or cry whenever he is denied something he wants, even though he is no longer a baby. However, he is still a baby in his emotional behavior. Most grown people react reasonably when they do not get everything they want. They realize that not every desire is satisfied at once. They wait.

How can the tantrum habit be broken? Here is a girl who goes into a rage whenever she is denied something. She wants to break the habit. (Step 1, p. 36.) She realizes that she will not be able to get along with other people or her friends. She analyzes the habit and finds that it is probably "left over" from her baby days. (Step 2.) What can she substitute? One way to break this habit is to substitute the habit of counting 50 whenever she begins to fly into a rage. (Step 3.)

24 *At birth a baby reacts by reflex and instinct, but it soon begins to learn by conditioning. What are some of the early habits of the baby?* (*Photo by Morton Berger*)

Do you fight at the drop of a hat? Do you become angry easily? Do you lose your temper? Count up to 50. If that isn't enough, count up to 200 if necessary. By that time, the first full anger will have passed away, usually. Counting to 50 is merely a substitute for the moment. After you have counted and are calm, try to find the reason for your action. You will probably realize that whatever the reason was, the tantrum was not a useful or desirable reaction. We can't always have what we want.

Your reward will be the respect of your fellows, and what is more im-

portant, you will have your own self-respect. For as you learn to control your behavior, your ability to improve it will increase rapidly.

LEARNING

Sultan was a fine chimpanzee. He was trying to get a banana that was outside of his cage beyond his reach. In his cage were two sticks, each one too short to reach the banana. If you had been there, you would have seen that one stick could be fitted into the other. Fitted together, the two sticks would reach the banana.

After some attempts to reach the banana with his arms alone and then with each stick separately, Sultan apparently gave up in disgust. He sat down in his cage; he wandered about. Then suddenly he ran to the two sticks, put them together, and reached the banana. He had solved his problem.

LEARNING ABOUT LEARNING

Why bring Sultan into the picture? His actions are an example of the way an animal learns to solve a new problem. A child of five or six might have figured it out.

Sultan, however, is not a human being. Compare the size of his brain with yours in proportion to body size (Fig. 10). You have much more brain material. However, you should not make the mistake of thinking that it is the size of the brain alone which is responsible for man's ability to learn and think. The largest human brain ever measured was that of an idiot. This merely emphasizes that we do not know yet what in the brain enables men to learn. We do know that there are certain methods of acting that help people when they are faced with a new problem. What are these methods?

SOLVING A NEW PROBLEM

First, recall your past experiences (your old pathways in the nervous system) and bring them to bear on the present problem. Also, especially if you have had no experience which bears on your problem, go to other people for advice.

Second, select the one experience which is most likely to help you solve the present problem.

Third, think into the future. In other words, plan ahead.

The ability to recall his experiences, to select the one which is most likely to succeed, and to plan ahead enables man to solve problems that would baffle any other animal in the world.

One of the problems which you will soon have to solve is this: What shall I do after I graduate from high school?

Recall how others have solved this problem. Some have gone to work, others to college, others to trade school. Then seek other people's advice (in other words, get their experiences). Next, select the solution which is most likely to help you. Now you can plan your future. You will select the courses to take in high school. You will plan the things you will have to do before you enter college or go to work. Then you will carry out the plan. This is intelligent behavior.

Here you have the method by which good thinking is carried out. It is the same method which will help you learn well. Learn to learn well by attacking each problem you have in this way.

1. Recall past experiences which are likely to help with the present problem. If necessary, get someone's advice (experience).

2. Select the method which will help you.

3. Plan the method of attack and carry it out.

If you analyze the behavior of the great scientists, you will realize that they planned their work exceptionally well. Furthermore, their plans were based on their selection of methods from their own previous experience, and the experience of other scientists. How they carry out their plans is one of the characteristics of the scientist's special method of thinking. An attempt has been made to weave that method into every page of this book. It is so important in the world's work that we shall spend some time with scientists at work in the next chapter. The scientist's way of carrying out his plan of work is largely responsible for the scientific age in which you live.

LEARNING TO STUDY

You have a very important job on your hands. Your job is learning to learn well. The knowledge you have gained about your nervous system can help you improve your learning methods. We will concentrate here on learning at home; that is, learning by yourself without the teacher's help. You are going to form new pathways in your nervous system without help. A teacher is a person who has spent many years in learning how to help others to learn well.

For instance, are you reading this at home? Is your dictionary by your side? Are the reference books you need by your side? Do you have pen and ink, pencil, ruler, blotter? Is the lighting good? Is it quiet enough for you to study?

STEP 1. DEFINING THE TASK

We know that a student of your age is a busy person. You have many things you want to do. But the job with highest priority is to learn well. The first thing needed in efficient learning is a clear statement to yourself of the problem to be solved, or the things which need to be done. This is what is meant by "defining the task."

STEP 2. MAKING A PLAN

Once the task is defined you should recall, and you will probably do it automatically, those experiences which you have found useful in the past in working on similar problems. On the basis of those experiences you can make your plan. "This is the way I will do it," you will say. If it is an English composition, you will make an outline. If it is a science project, you will make an outline and a sketch. If it is an algebra problem, you will have a note on a previous method used to solve problems in mathematics or a reference to a page in your mathematics text. Whatever it is, you will work out a plan. Efficient learning grows out of efficient planning.

STEP 3. PROVIDING THE TIME AND MATERIALS

Once you have a plan, you can get to work. In order to work, you need to set aside the time and provide the materials to carry out the plan. Experience has shown that those who set aside a regular time, let us say from 4 to 6 or from 7 to 9 each day, finish their work. Some students may need more time, others less. But whatever time you choose, be sure to have the materials you need.

Your place of work should be near your reference books. You should have writing materials, ink, sharpened pencils, blotter, ruler at hand. Why? You may be able to rewrite a sloppy paper but you will never be able to make up the time lost on account of unnecessary interruptions. You will take more time to do your job if you have to get up each time you need ink or a pencil.

STEP 4. PROVIDING PROPER SURROUNDINGS

Before you read this, do experiment five in the activities on page 41. It is almost useless to try to tell boys and girls that it takes more time to study with the radio on, or with noise about them, than it does in a quiet place. They almost always say, "But the radio helps me to study." Does it? Try the experiment and see for yourself. For efficient learning you need a quiet place in which to study. The most efficient studying occurs when you are attending to one stimulus—not two or three, coming from your radio, your television set, or your friends.

READING EFFICIENTLY

Unless you learn to get the main idea from a paragraph or chapter you will not benefit from your studying. Many students conscientiously do their assignments but find that they cannot remember much of what they read. Here is a method that will prove useful to you if you have this difficulty.

When you finish a paragraph, summarize its main idea in one short sentence. Then write this sentence in your notebook, which should always be at your side. Can you do this? Prove it to yourself. Read the first paragraph on page 27 and write its main idea in one complete sentence. Are you able to do it?

You have heard people say of a person, "He reads well, and gets everything from what he reads." Such a person can put his reading into clear sentences. He can get the thought of each paragraph. He does not try to memorize each sentence; rather he puts the main idea into his own words. His cerebrum is at work.

THE HABITS OF EFFICIENT LEARNING

Once you learn how to study *efficiently*, you will learn as *efficiently* as it is possible for you to do. You will get a habit which will be important to your success.

William James, the great psychologist, concluded his famous essay on habit with the following paragraph:

> Let no youth have any anxiety about the upshot of his education, whatever the line of it may be. If he keeps faithfully busy each hour of the working day, he may safely leave the final result to itself. He can with perfect certainty count on waking up some fine morning to find himself one of the competent ones of his generation, in whatever pursuit he may have singled out.

The competent person is the one who has been able to change or modify his behavior along lines which bring success. Man's ability to modify his own behavior through learning is his most important characteristic. Upon it depend man's future and your future.

GOING FURTHER

1 *Experimenting with plant behavior.*

1. Have you ever made a pocket garden? Take some radish seeds and soak them in water for 24 hours. Now take two small square pieces of glass about the size of a lantern slide and place two pieces of blotter (about the same size as the glass) between them. Space the radish seeds about a half inch apart on the blotter. Now you have a blotter with radish seeds sandwiched between two pieces of glass. Keep the glass plates together by means of a rubber band. Keep the blotter moistened with water. After a few days the seeds will produce stems and roots. Keep the glass plates standing on one edge. In which direction do the roots grow? Turn the glass plates on another edge. Now what happens to the roots and stems?

2. Take a geranium or a similar plant and place it near a window. What happens to the leaves within 48 hours? Why?

2 *Experimenting with animal behavior.* If you

have a bottle of fruit flies in your school laboratory, you may discover their responses to certain stimuli. Shake the bottle of flies into a large glass cylinder. Quickly plug the cylinder with cotton or cork. In which direction do the flies travel? Turn the cylinder upside down. In which direction do the flies travel now?

Turn the cylinder with one end toward the window. In which direction do the flies travel? What do you conclude regarding the reaction of fruit flies to the stimulus of gravity? Or light?

3 *Experimenting with conditioning.* Can you get a goldfish to rise to the corner of an aquarium just by putting your hand over the corner? (Hint: A goldfish will rise to snap at fish food—the original stimulus.)

4 *Experimenting with habit formation.* Dictate a few sentences of a paragraph on p. 23 to your classmates. Ask them to write it as you dictate. Time them. Now ask them to write it from dictation again but this time omit crossing their "t's" or dotting their "i's." Give them the same amount of time used before. How many can complete their copying in the time allowed? Why?

5 *Experimenting with learning.*

1. Memorize the first stanza of the poem below with the radio tuned to a good mystery program or baseball game. Time yourself. Memorize the second stanza in a quiet room. Time yourself. Which took longer? Why?

Flee from the crowd and dwell with truthfulness;
Suffice thee with thy goods, tho' they be small:
To hoard brings hate, to climb brings giddiness;
  The crowd has envy, and success blinds all;
  Desire no more than to thy lot may fall;
Work well thyself to counsel others clear,
And Truth shall make thee free, there is no fear!

Torment thee not all crooked to redress,
Nor put thy trust in fortune's turning ball;
Great peace is found in little busy-ness;
  And war but kicks against a sharpened awl;
  Strive not, thou earthen pot, to break the wall;
Subdue thyself, and others thee shall hear;
And Truth shall make thee free, there is no fear!

—Geoffrey Chaucer, "Ballade of Good Counsel"
(modern version by Henry van Dyke)[1]

[1] From *The Poems of Henry van Dyke*, published by Charles Scribner's Sons.

2. Memorize the three lists of words below. Time yourself. Which took longest? A half hour later try to repeat each list in order. Which do you remember longest? Why?

certain	gewiss	naitrec
born	geboren	nobr
science	Wissenschaft	niecese
Joseph	Seppel	Sephoej
always	immer	swayla
never	niemals	revne
heaven	Himmel	nevhea

6 *Words are ideas.* Can you use each of these key words in a sentence which will give its meaning? Use the glossary.

nerve cell	impulse
nerve	habit
cerebrum	conditioned act
cerebellum	stimulus
reflex	response
medulla	brain
nerve pathway	axon

7 *Put on your thinking cap.*

1. "I disliked him instinctively," said Mr. Doe. Now that you have learned something of the way living things behave, what would you tell Mr. Doe to convince him that likes and dislikes of people are not instinctive?

2. "You can't teach an old dog new tricks," is a common saying. Is it true? How would you go about teaching an old dog a new trick? (See pp. 33–34).

3. Can a plant learn? Explain your answer.

8 *Test yourself.* In your notebook, complete the following statements with a correct word or phrase. Do not mark this book.

1. Man is dominant on earth because of his ...... At birth, man has two kinds of acts, ... and instincts. Later, as he learns, he develops habits.

2. Each act starts with a ...... to which there is a response. The impulse is carried along ......, which are composed of ......

3. If we dissect the brain of a frog we find it consists of three parts found also in man, the ......, ..., and ...... Without the ...... man could not think.

CHAPTER 3

MAN—GETTING AT THE TRUTH

First scene: a Swiss patent office in the late nineteenth century. Here is a young man bent over his desk working on patent papers. Sometimes, when the work is finished, he takes out a pad and covers it with numbers and formulas. At night he works even harder at his calculations. Later these formulas bring this man everlasting fame. His tools are paper and pencil, not test tubes or machines. With them he works out his Theory of Relativity and some of the ideas which are basic to our understanding of the world in which we live. You may have guessed that we are describing Albert Einstein (Fig. 25).

Second scene: the garden of a monastery at Brünn, Austria in the year 1850. Here is one of the monks tending some garden peas. Patiently he records the results of mating some tall plants with dwarf ones. If we stop to talk with him we learn that he has been growing and mating garden pea plants for some ten years. Perhaps you have recognized Gregor Mendel, the great scientist, whose work formed the basis of our understanding of the way we inherit our characteristics. His discoveries are the fundamental ones in the science of heredity.

Third scene: France in the closing years of the nineteenth century. Here is a man sitting patiently in a field watching some garden spiders. Farmers going to their work in the early morning find him at work. When they return in the evening, he is still observing patiently, quietly. All his observations he notes in his book. This is the great French naturalist Fabre, who described for us the life histories of many insects and spiders. His work is of the utmost importance in giving us knowledge for the fight against insects which eat our crops, carry disease, and rank as man's most numerous enemies.

Fourth scene: Berkeley, California in 1939. We may find Dr. Ernest O. Lawrence and his assistants in a huge laboratory filled with complex machinery. Here is a cyclotron (sī′klô trŏn) with which atoms can be smashed (Fig. 26). It is the machine with which Dr. Lawrence helped figure out the structure of the atom. For this work he won a Nobel prize. How does one recognize the scientist? Is it by the place in which he works?

25
Can you recognize in this young man the greatest scientist of our time? Here is Albert Einstein as he looked in 1905. (Lotte Jacobi)

RECOGNIZING THE SCIENTIST

We saw Einstein in the patent office, Mendel in his garden, Fabre in the field, Lawrence in the laboratory—all scientists, whose discoveries are of importance to mankind. Clearly, the place in which he works is not a reliable indication that a man is a scientist.

It is also clear that what a man works on will not tell us that he is a scientist. For the four great scientists we observed were working in four different fields. Perhaps it is not where they work or what they are doing, but rather how they work which tells us whether they are scientists or not.

FRANCESCO REDI

There is the case of Francesco Redi (frän chĕs′kō rā′dē) who lived in Italy in 1670. At this time people commonly believed that the maggots of flies (the so-called worms which hatch from flies' eggs) came from decaying meat. But Redi doubted that living things (the maggots) could come from a dead thing (the decaying meat). What did he do about it?

First of all, he didn't accept the belief that maggots came from meat just because some great men of his time held that opinion. He wanted to find out for himself. Second, he did not sit down with others and argue the

matter and come to a conclusion on the basis of mere talk. Instead, he began a search for the *evidence*, for the *facts* from which he could get an answer to the problem, "Do maggots come from meat?" Read for yourself his own words, translated from the Italian.

Having considered these things, I began to believe that all worms found in meat were derived directly from the droppings of flies and not from the putrefaction [spoiling] of the meat, and I was still more confirmed in the belief by having observed that before the meat grew wormy, flies had hovered over it, of the same kind as those that later bred in it. Belief would be vain without the confirmation of experiment, hence in the middle of July, I put a snake, some fish, some eels of the Arno, and a slice of milk-fed veal in four large wide-mouthed flasks; having well closed and sealed them. I then filled the same number of flasks in the same way, and left these open. It was not long before the meat and the fish, in these second vessels, became wormy and flies were seen entering and leaving at will; but in the closed flasks I did not see a worm, though many days had passed since the dead flesh had been put in them. Outside on the paper cover there was now and then a deposit, or a maggot that eagerly sought some crevice by which to enter and obtain nourishment. Meanwhile the different things placed in the flasks had become putrid and stinking; the fish, their bones excepted, had all been dissolved into a thick, turbid fluid, which on settling became clear; with a drop or two of liquid grease floating on the surface....

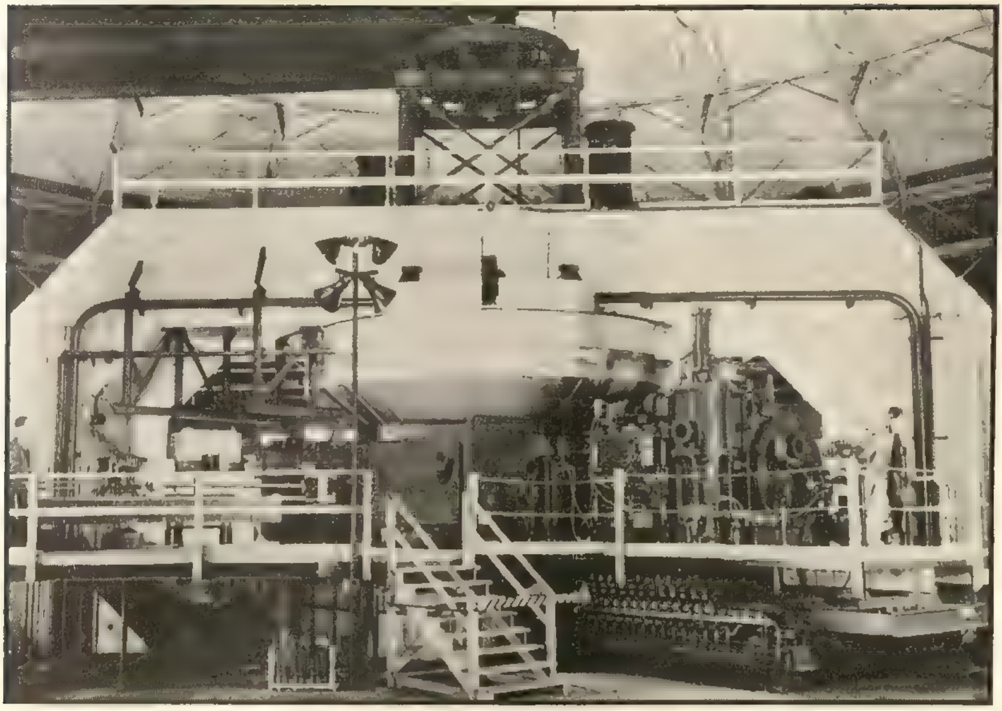
Leaving this long digression and returning to my argument, it is necessary to tell you that I thought I had proved that the flesh of dead animals could not engender [produce] worms unless the semina [eggs] of live ones were deposited therein. Still, to remove all doubt, as the trial had been made with closed vessels into which the air could not penetrate or circulate, I wished to attempt a new experiment by putting meat and fish in a large vase closed only with a fine Naples veil, that allowed the air to enter. For further protection against flies, I placed the vessel in a frame covered with the same net. I never saw any worms in the meat, though many were to be seen moving about on the net-covered frame. These, attracted by the odor of the meat, succeeded at last in penetrating the fine meshes and would have entered the vase had I not speedily removed them.

You can see that he had a plan of work:

First, he studied the problem carefully and made a plan for finding out how the maggots got into the meat. In his own words "I began to believe that all worms found in meat were derived directly from the droppings of flies and not from the putrefaction of the meat." Scientists call a guess or preliminary statement such as Redi's, which is based on a few facts or observations, a *hypothesis* (hī pŏth′ē sĭs). A hypothesis is but the beginning of a scientist's experimental procedure.

Second, he gathered and recorded more facts to determine whether his hypothesis was valid. He did this by devising many experiments which would enable him to observe the facts he needed. He kept careful records for he knew that the memory is often faulty.

In one of his experiments he prepared three jars with a piece of meat in each (Fig. 27). He left one open; he covered one with a type of cheesecloth; and he made another airtight. He saw many times, not just once, that flies were attracted to the meat in the open jar and laid their eggs on it. These eggs developed into maggots. Flies were rarely attracted to the airtight jar because, as Redi supposed, the odor of decaying meat could not reach them. Flies were attracted to



26 *An atom smasher at the University of California. Compare its size with the man at the left. In their work scientists use many different kinds of tools, from books to cyclotrons. (U.S. Signal Corps)*

the jar covered with cheesecloth because the odor passed through the cloth. The flies, though, could not get into this jar to lay eggs on the meat. On the basis of many observations, Redi concluded that maggots came from flies' eggs, not from meat. He needed all three jars to discover whether maggots came from the meat or from the flies' eggs. Can you see why?

Third, Redi repeated his experiment many times. He did not come to his conclusion from one fact found by one experiment. He could always refer to his careful records for the data of his previous experiments.

Fourth, he did not keep his discovery secret. Scientists believe that knowledge is the property of mankind. He published his conclusions so that other scientists could repeat his experiments and thus check his work.

In short, Francesco Redi used several procedures for getting at the truth. First, he defined his problem, developed a hypothesis, and made a careful plan of experiment to test his hypothesis. Second, he made many observations to enable him to get at the facts necessary to test his hypothesis. Third, he came to a conclusion only after many observations, only after he had obtained many facts by repeating his experiments many times. He tested his conclusions time and time again. Fourth, he published his results so that other scientists could repeat his experiment and verify or check his results. Are these procedures characteristic of the work of other scientists?

RECOGNIZING THE SCIENTIST— ANTOINE LAVOISIER

Some 175 years ago, it was believed that when a substance burned it lost weight. It was thought that a fiery substance called phlogiston (flô jĭs′tŏn) went up in the air. And this seemed perfectly reasonable. For instance, when a huge log of wood burned down, all that was left seemed to be the ashes, which could be carried out in a pail. A grown man had all he could to to carry the log into the room, while a child could carry the ashes out. However, on the basis of many observations, Antoine Lavoisier (äɴ′twån′ lå′vwå′-zyā′) believed that when a substance burned it gained weight, not lost it as would be expected on the basis of the phlogiston theory. This was his hypothesis. How did he go about testing this hypothesis?

Lavoisier planned several experiments to answer the question, "What happens when substances burn?" He burned sulfur, phosphorus, mercury, and tin (Fig. 28). When he burned these substances in a closed vessel, he found that they combined with about one-fifth of the air in the vessel. (You know from your previous study of science that this is the amount of oxygen in the air).

He also found that, in burning, these substances gained weight. He determined this by weighing the substance carefully before and after burning. He did these experiments many times, observing carefully and keeping accurate records. Thus he came to the conclusion that when substances burn they gain weight by combining with a portion of the air. And he published his conclusions.

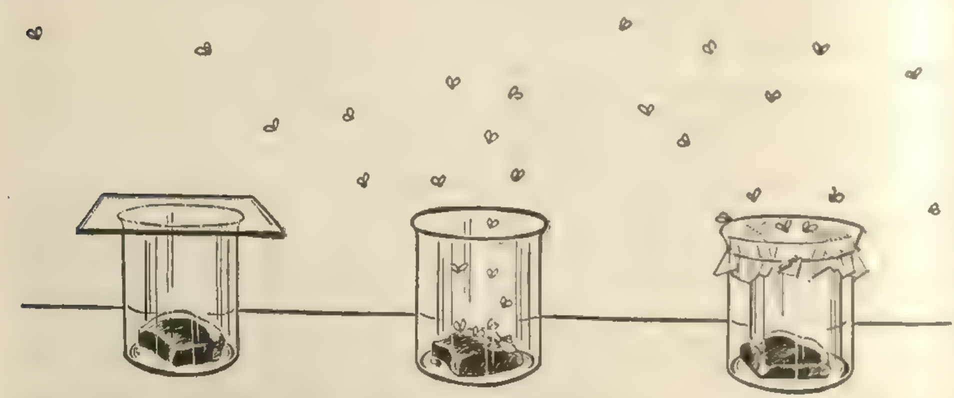
When we analyze Antoine Lavoisier's work, we find the same pattern which we saw in Francesco Redi's work. We find:

1. Careful planning to solve a problem. This includes a hypothesis or several hypotheses.

2. Careful observations and recordings of facts found through experiments repeated many times. The hypothesis is verified (proved) or rejected on the basis of the facts.

3. Drawing conclusions only from accurate observations.

4. Publishing his work so that other scientists might verify his conclusions.



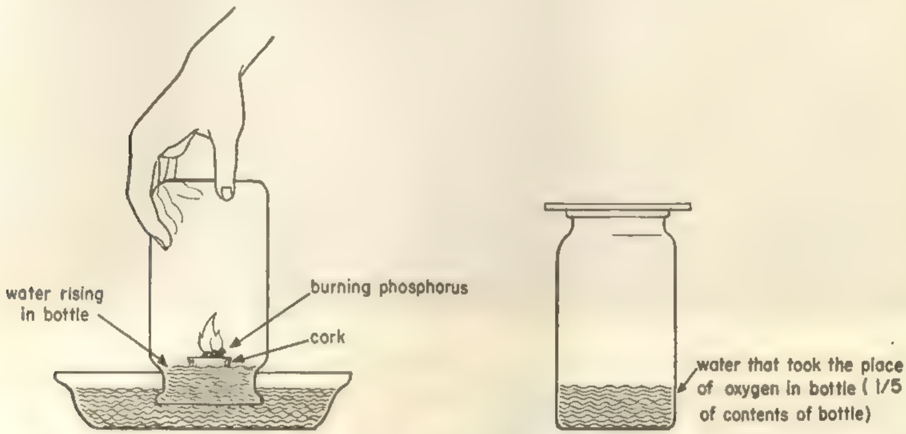
27 *A diagram of Redi's experiment. Read Redi's description of his experiments on page 44. Which jars are the controls (p. 51)?*

This method seems entirely reasonable, doesn't it? It also appears simple to follow. If you examine carefully the methods used by Redi and Lavoisier, you see that the key step appears to be accurate observation. Only by accurate observation can a hypothesis be verified or rejected.

One careful student of the method scientists use has offered this definition. He calls scientific method "*the method of verified hypotheses.*" Whether we agree with his definition or not, he has underlined an important part of the scientific work, namely, verification of the hypothesis through careful observation. Professor P. W. Bridgman, one of the great scientists of our time, thinks that one cannot really define scientific method. One of his favorite definitions is that science means *doing one's best with one's brain, no holds barred.* What he is really saying is that different scientists work in different ways, that there is really no one way in which scientists solve a problem in which they are interested.

HOW A SCIENTIST STARTS WORK

Where does a scientist get the problems on which he works? There are many ways. A problem may be suggested to him by his reading of other scientists' work or by listening to scientists who are presenting their work before colleagues. He may observe a curious fact in his laboratory or in the field. Or he may have a problem suggested by a teacher or co-worker.



28 *A modern demonstration of one of Lavoisier's experiments. When phosphorus (floating in a metal boat on the cork) is burned, it combines with the oxygen in the air. Why does the water rise to occupy only one-fifth of the bottle?*

Once a scientist becomes interested in a problem and has made his observations, he attempts to find out whether there are other facts related to the one he has discovered. For instance, when Lavoisier became interested in the problem "What happens when things burn?" he tried to relate the facts on the combining of oxygen with wood (burning) to the combining of oxygen with different metals and to the combining of oxygen with food. He tried to relate the facts he discovered to each other, to find out whether there was any order into which they might fall. When a large number of facts

29 *This is a photograph of the sky over Paris without the use of a telescope. Compare this picture with Fig. 30, in which the sky is seen through a telescope. (American Museum of Natural History)*

falls into some order we have a *theory*. A theory is a statement which attempts to explain the facts discovered.

THE THEORY

For instance, on the basis of all the facts Lavoisier discovered about burning he formed a theory of burning. His theory states that when a substance burns in air it combines with oxygen. His experiments supported this theory. Furthermore, on the basis of this theory one could predict the results of new experiments on burning. For instance, if we burn the metal magnesium (măg-nē′zhĭ ŭm) we may predict that it will combine with oxygen. And it does. If it didn't, we should have to modify the theory of burning.

On the basis of many facts, scientists have proposed the theory that living things come from other living things. We may, therefore, predict that any given thing, let us say a bacterium, must have come from another bacterium like it. If this were not so, then we should need to modify the theory.

Put another way, a theory is the ordering of many related facts. It has been said that scientists are always on the search for order in the universe. However, before facts can be put in any order, they must be discovered. And that is the business of scientists. But to make accurate observations they must use methods which will insure accuracy.

TOOLS FOR GETTING FACTS

Probably you don't see any reason for making a fuss about methods used for accurate observation. After all, one can make careful use of one's eyes, one's ears, and other senses. But scientists have learned it is necessary not only to check and double-check what their senses report but also to use instruments to aid the senses.

HELPING OUR SENSES

Look up into the sky on a clear night. How many stars can you see (Fig. 29)? Now look at a picture of a tiny portion of the sky made through a powerful telescope (Fig. 30). How much more can you see now?

You have seen a jar of clear water taken from a pond. When it is strained through a fine net it looks like an ordinary glass of water. When the pond water is seen through a microscope, however, you get a more detailed picture than you would with the eye alone (Fig. 31).

Now take up a glass of water. How warm is it? You may guess. Now put a thermometer into it and read the temperature. You know much more accurately how warm it is.

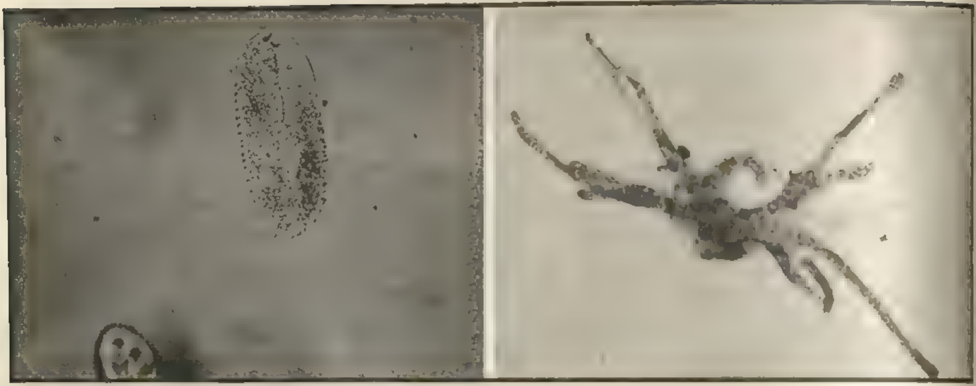
These examples are given merely to show you that scientists do not rely upon their senses alone. They use instruments which are more accurate. They try to measure what they see.

Test your own senses. Measure the lines in Fig. 32 with your eyes alone. Which one is shorter, *a* or *b*? Now try a ruler. What do you conclude?

Of course you would agree that the more times a measurement is taken the more accurate will be the final result. Thus one scientist who was determining the temperature of a snake recorded these temperatures in his notebook: 18° C. (centigrade), 18.1° C., 18.0° C., 18.1° C. These were taken at the same time, at two o'clock in the afternoon. This is typical of the way scientists work; they take many measurements. Another way of saying this is to state that they always make many observations before coming to a conclusion. Measurement is basic to scientific investigation.

But it must be clear to you that a scientist cannot take time to measure everything with which he comes in contact. If each scientist who was working on a cure for a disease had to start

30 *The sky seen through a telescope when the planet Pluto was discovered. The arrows point to the newly identified planet. What is the difference between this view and that in Fig. 29? (American Museum of Natural History)*



31 *A glass of pond water may appear fairly clear to the naked eye. But when you examine the water under the microscope you may find such single-celled animals as the paramecium* (left) *and the amoeba* (right) *shown in this photograph. When the scientist makes his observations, should he trust his naked eye?* (Left, *Bausch and Lomb*, right, *Jacques Padawer*)

afresh, progress would be impossibly slow. Accordingly it is necessary that a scientist read what others have done before him. But how can he be assured that what he is reading is accurate?

MAKING CERTAIN OF ACCURACY

Even if he wished to, a scientist could not repeat all the experiments about which he reads. He accepts many of them even as you accept many facts you get in this book without personally checking them. Probably it would take more than your lifetime to check each one of the facts in this book even if you had all the instruments and all the knowledge necessary.

Scientists, first of all, rely on each other's honesty. Dishonest people cannot and do not last long in science. They are soon discovered because each scientist builds on facts reported by others. Inaccurate observations or dishonest reports are soon exposed.

Sometimes a mistake is honestly made. For instance, the Roman physician Galen (gā'lĕn) taught that man's thighbones were curved. He got this observation from dissecting the body of a chimpanzee. Since he thought man was like the chimpanzee, he concluded that man had the same structure. In 1543, the Italian scientist Vesalius showed that man's thighbones were straight. These facts he obtained from examining human bodies. Galen's statements concerning man's thighbones were discarded.

The main reason that scientists can rely on each other's observations is that they follow the same rules. First, they make certain that their instruments are accurate. Therefore their measurements are accurate. Thus Lavoisier's experiments on burning would have been useless if he had used inaccurate scales to weigh his substances before and after burning (p. 46). An ordinary camera or the naked eye is a useless instrument for examining the microscopic animals in a drop of water.

Second, in describing their experiments scientists always make certain to describe the exact conditions under

which each experiment was conducted. For instance, Lavoisier described and even made drawings of his apparatus. Other scientists could repeat the experiment if they doubted the results.

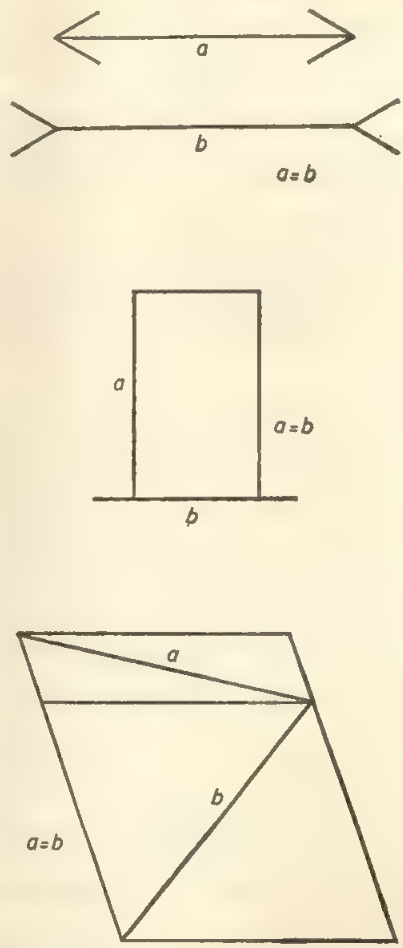
Third, most experiments include what scientists call a *control* experiment, which serves as a check on the accuracy of the whole experiment. Such experiments have two parts: the actual experiment and the control experiment.

THE CONTROL EXPERIMENT

Do you remember Redi's experiment (Fig. 27) to answer his question, "Are flies responsible for the maggots in meat?" Recall that he had one jar in which flies were permitted to get to the meat to lay their eggs. The second jar was identical except that the flies could not get to the meat to lay their eggs. Maggots appeared in the meat in the first jar but they did not appear in the second jar. The second jar served as the control. It is a check on the actual experiment. The control experiment eliminates the condition the scientist is investigating. Redi believed that flies were responsible for the maggots in decaying meat. Therefore, he eliminated the flies in his control experiment.

Do you think you can set up a control experiment? Try this one. You have seen moldy bread. Is moisture necessary in order for mold to grow on bread? Let us first set up the actual experiment (Fig. 33). We expose a piece of bread until it is absolutely dry. Then we moisten it with water and place it in a dry jar. We close the jar tight. Now what is the control experiment? We do exactly the same thing, use the same kind of jar, the same kind of bread, keep both jars in the same place, with one exception. We do not moisten the second piece of bread. We compare the two after a week. Is this enough to come to a conclusion? Not at all. We have neglected to repeat the experiment many times. Only after several repetitions of the experiments by many observers who confirm our results can we come to a truly scientific conclusion.

When Dr. Alexander Fleming discovered penicillin, he asked himself,



32 *Compare* a *and* b *in each of these three figures. Which is longer,* a *or* b*? In each case* a *and* b *are equal. Check this with a ruler. Should you trust your eyes in all cases?*

"Does the mold Penicillium really destroy germs?" He, therefore, added Penicillium to cultures of germs. He found that the germs died. What do you think his control experiment was? In his control experiment, he eliminated the condition he was investigating. He did not add Penicillium to his controls. In the control experiment, the germs grew and multiplied.

HOW SCIENTISTS WORK

Now that we have seen how some of the great scientists work, let us summarize their methods of work.

1. A scientist starts his work by setting forth his problem clearly. You recall that Lavoisier asked, "What happens when substances burn?"

2. A scientist tries to discover all that is already known about the problem. Lavoisier read the works of others; thus, he knew of the work on phlogiston.

3. A scientist carefully plans to use all possible methods which will help him solve the problem he has set for himself. In this planning scientists try to "guess" at a possible solution of the problem. Then they plan their experiments around this guess. Such a guess is called a hypothesis. For instance, Redi's scientific guess or hypothesis was that the maggots in the meat came from flies which laid eggs on it, not from the meat itself. If the facts that a scientist gathers do not support his hypothesis, he will discard it and form another. In other words, a hypothesis helps give direction to the scientist's experiments.

4. A scientist repeats his experiments and records his observations many times before he is satisfied with a conclusion. Lavoisier burned mercury, tin, wood, and other substances before he came to a conclusion about burning.

5. A scientist generally makes his methods and conclusions known so that other scientists may check his results.

Does the successful completion of an experiment end the work of the scientist? On the contrary, it leads to more problems. For instance, once Lavoisier had concluded that a burning substance increases in weight, he asked himself, "What is the cause of this increase in weight?" After he concluded that the increase was due to a substance in the air, he asked, "What is this substance?" He continued to find more and more problems after each conclusion till his death ended his work.

It is clear, then, that it is the methods they use that tells whether men are scientists—not where they work or what problem they choose to investigate. Men of science seek the truth by doing experiments, by making observations in search of the meaning of ordinary things which happen in nature. Scientific methods enable scientists to look for the facts, check the facts, conclude only from the facts. That is the way they solve problems of life and living. The methods are troublesome perhaps. But they are certain and trustworthy. The methods you have been reading about are the foundations of science.

WHO BECOMES A SCIENTIST?

Next time you go to school look about in your classroom and ask yourself who in the class is likely to become a scientist? Will it be John, so seriously at work in a corner of the laboratory? Will it be Sue, who is reading in another seat? Will it be Ted, who has that dreamy look in his eye? Will it be you? This is a hard question to answer be-

cause so far no one has devised scientifically reliable methods for selecting a scientist. But we can begin to search for an answer by asking, "Who can use scientific methods?"

CITIZENS USE SCIENTIFIC METHODS

Any intelligent person can use scientific methods. For example, let us go along with Mr. X who goes for a Sunday drive. Along the way, the engine stops running and his car stops. Notice the way he behaves. He checks every trouble spot—the gasoline supply, the fan belt, the battery, the ammeter, the spark plugs, the oil, the water, till he finds what is wrong. Then he knows what to do about it.

He has obtained the many facts from which he can get at the true cause of the trouble. Of course, Mr. X was concerned with a simple problem, but he used careful observation, a scientific method of finding a solution for his problem.

Mr. Y is ill. He has a bad cough. He doesn't hang a walnut around his neck as his superstitious neighbor advises him to do. He doesn't try Follum's Cough Medicine. He doesn't ask his druggist. He goes to a trained expert, his doctor. The doctor uses his instruments to get at the true cause of his illness. If the doctor doesn't know, he calls in another expert. Mr. Y is using a scientific method.

Mr. L is a farmer. His agricultural magazine contains an advertisement which states that Magno-Fertilizer is better than any fertilizer known. Mr. L could throw out the fertilizer he has been using. But he doesn't. He may buy a few sacks of Magno-Fertilizer and try it on several acres of wheat, but the other acres are treated as before. He also asks the county agricultural expert. He also writes to the state agricultural station. Farmer L is using a scientific method.

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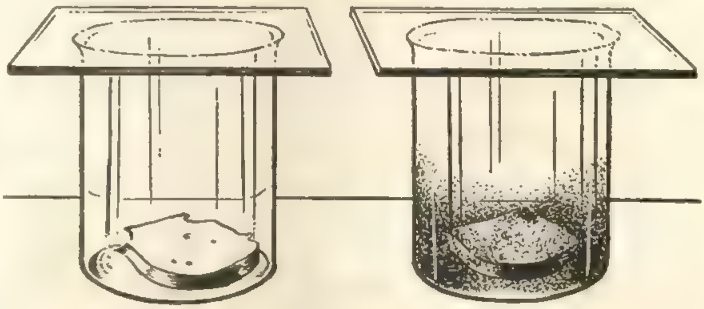


An experiment to determine whether moisture is necessary for the growth of mold. The jar on the right *has moist bread, the one on the* left, *dry bread. Which is the control?*

If you try to come to a solution of any problem from one fact or only a few facts, you may find yourself in the position of the six blind men who, the story tells us, were trying to discover the nature of an elephant. They had never seen one. Yet each one came to a different conclusion, as you will see in Fig. 34.

Whenever you do away with guess work, superstition, or prejudice, and use all the facts you can get, plus the help of qualified experts, to solve your problems, you are using scientific methods. You become a citizen who uses science and its methods to solve your own personal problems. But there are also citizens who train themselves to become the science experts of the community.

SCIENCE EXPERTS

No one can hope to have the knowledge necessary to solve every one of his problems. For the solution of certain of these problems, we must go to experts. These experts may not be research scientists who make original discoveries of facts but they have the facts and know the recent discoveries in their field and can apply them to solving problems. Doctors, dentists, horticulturists, laboratory technicians, science teachers, engineers, inventors, and many others are able to apply the discoveries of research scientists. These people have spent years of their lives training themselves in the knowledge and skills needed to apply the facts of science. Thus a doctor spends four years in college, four more years learning medicine, and several additional years as an intern in a hospital learning to apply his knowledge.

It may be, however, that you will become a research scientist. Why not? We do know that intelligent people, with a strong sense of curiosity who are willing to work very hard, can become research scientists. How does one go about becoming a trained research scientist?

RESEARCH SCIENTISTS

One hundred years or so ago, a person became a scientist as soon as he began to make discoveries. William Henry Perkin (1838–1907) was such a person.

Perkin, an English schoolboy, was seventeen years old when he made one of the important discoveries of the nineteenth century. His teacher, knowing of young Perkin's interest in chemistry, suggested to him that he try to make quinine (kwī′nīn). As you know, quinine is an important drug used in destroying the germs of malaria. With his teacher's help, Perkin began to work after school hours. Experiment after experiment failed. But one day as Perkin began to wash out one of his test tubes, he noticed a beautiful color as the water dissolved the sticky mass of coal tar at the bottom of the tube. He repeated his experiment again and again. Each time he got a beautiful purple color called mauve (mōv).

Perkin and his teacher were excited. They knew that most dyes then in use had to be extracted laboriously and by expensive methods from certain animals and plants. Perkin worked harder and he came to his teacher for help in solving many of the chemical problems facing him. So it was that Perkin, trying to make quinine, in 1856 made the first dye, mauve, from coal. Ten years later he succeeded in making another dye, alizarin (*ȧ* lĭz′*ȧ* rĭn). William Henry Perkin had laid the foundation of the dye industry. Almost ninety years later, in 1947, Dr. Robert Woodward of Harvard, following some of Perkin's methods plus some of his own, made quinine.

Dr. Woodward, although just as intelligent as Perkin, could not start in the same way. At present the field of science is so complex that a great deal of training is needed before anyone can become a trained research scientist. Dr. Woodward went to college for four years. Then he obtained a doctor's degree in chemistry. In order to get a doctorate in science, a student must show his ability to do original research. Not only must he make some original discovery but he must also advance in his studies. This usually takes four to six years after college. So you see that nowadays a trained research scientist is tried and tested before he enters upon his work of discovery.

A research scientist, then, is one who

tackles unsolved problems in science. Sometimes physicians or engineers become research scientists. They discover for themselves that they are more interested in searching for the facts than applying them. They find enough work for there are ever-widening fields in science. Scientists are just beginning to discover the kind of world in which we live.

SCIENCE AND YOU

You may become a research scientist, or you may enter a profession which applies the findings of the research scientist. You may enter a nonscientific profession or business. Whatever you do, you will find that science affects you. For science is at least three things.

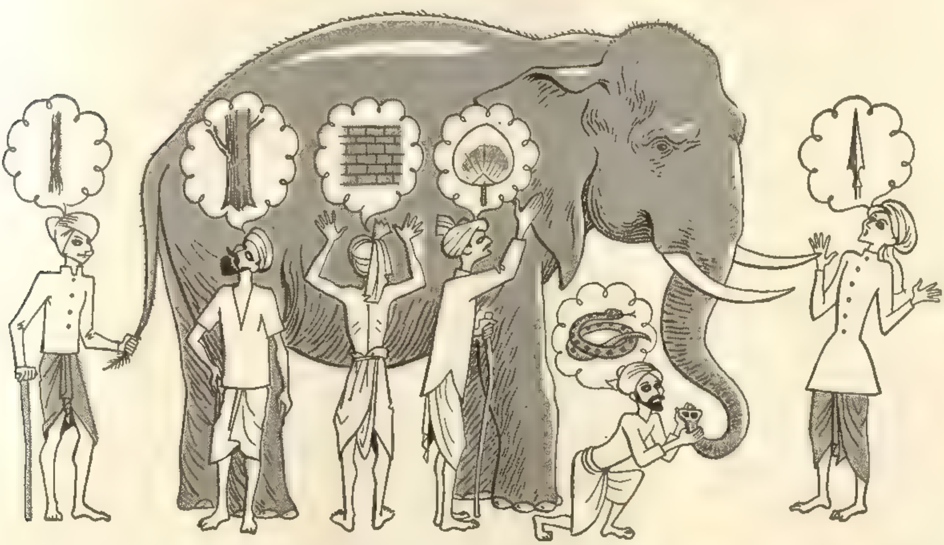
It is a *body of tried and tested information* which you will need to use throughout your life. For instance, you use scientific knowledge about diet and your personal health every day.

It is a *body of inventions* which has improved and will continue to improve your living. The telephone, radio, automobile, and airplane are just a few examples.

Finally, it is a *method of thinking* which you have already used and should use whenever possible to solve problems and to arrive at the truth.

You are living in a world where science plays an increasing part in your life. And as you read this book you will see how science affects you in your daily living. Now you know something of the way the discoveries of science have been made. This is only a beginning. Throughout the book you will learn how truly exciting the work and methods of scientists can be.

Look around again in your classroom today. Which of you will become scientists? Several of you may. However that may be, every one of you will be affected by science and scientists. And



34 *This illustrates the story of the six blind men and the elephant. Why did each one come to a different conclusion? Should you come to a conclusion from only one observation?*

every one of you will need to know how to use the scientific method to get at the truth.

GOING FURTHER

One of the most important things you can do in high school is to find out what you want to do as your lifework. Perhaps you may want to go into some field of science.

Form a committee on Vocations in Science. Ask your teacher to reserve for you a place on the bulletin board. Paint a sign MEN AND WOMEN WANTED. Under this title list different jobs in science, such as:

ENGINEERING	TEACHING AND RESEARCH
chemical	science teacher
civil	physicist
mining	geologist
electrical	biologist
automotive	chemist
aeronautical	

MEDICAL	AGRICULTURE
doctor	farming
dentist	horticulture
nurse	plant and animal breeding
X-ray technician	forestry
laboratory technician	county farm agent

SPECIAL FIELDS

entomologist (insects)
ichthyologist (fishes)
herpetologist (reptiles)
ornithologist (birds)
astronomer (the universe)
meteorologist (the weather)

For information about many positions in government service, write to the Department of Interior, Washington, D.C. The department will send you the requirements for the position of Junior Biologist, Junior Chemist, Junior Geologist, and Junior Physicist and many of the other positions listed above.

Your library will have many good books on vocations in science.

UNIT TWO

EXPLORING THE EARTH

A V–2 rocket at White Sands Proving Grounds, New Mexico. Rocket experimentation today is revealing new facts about the outer atmosphere. Tomorrow the secrets of the moon, even those of other planets, may come within rocket range. (*U.S. Air Force*)

Will man ever reach Mars or the moon?

Here is part of a story from the New York *Times* of July 6, 1947, which deals with man's hope of conquering interplanetary space, the space between the planets.

"Dr. Lyman Spitzer, Jr., Associate Professor of Astrophysics at Yale University, predicts that since we have in uranium a rich source of energy, it may well become possible to voyage in interplanetary space within our lifetime."

Then the story goes on to say:

"Dr. Spitzer thinks it more likely that men will set foot on the planet Mars before they land on the moon, because Mars has an atmosphere and the moon has none. On Mars a space ship could glide gently to the surface.

"'That there may be intelligent life on Mars is probable to some astronomers,' says Dr. Spitzer. Assuming that life on Mars developed earlier than it did on earth, the Martians may have been civilized for millions of years, as compared with our thousands. 'In such a case, Martian scientific knowledge, and Martian understanding of nature would, of course, be enormously greater than ours,' Dr. Spitzer concluded. 'In fact, men from Mars may have already visited the earth. Unless they had spent some time in a large city or had landed sufficiently recently to be photographed,' he said, 'we would have no record of their having been here. And the few men who had seen them would probably not be believed by anyone else.'"

Notice in the *Times* article the use of the words "probable" and "assuming." Dr. Spitzer isn't certain at all. He makes no claims that there is life on Mars because he doesn't have the facts. But throughout the world, scientists are trying to get the facts. For instance, in a recent article in the magazine *Army Ordnance*, Dr. Fritz Zwicky of the

A V-2 rocket at White Sands Proving Grounds, New Mexico. Rocket experimentation today is revealing new facts about the outer atmosphere. Tomorrow the secrets of the moon, even those of other planets, may come within rocket range. (U.S. Air Force)

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California Institute of Technology announced that he and other scientists hope soon to send rockets or other bodies beyond the earth's atmosphere.

In the coming months and years, newspapers and radio will feature stories of man's attempt to conquer the space between planets. There has been serious mention of setting up a man-made satellite in the space beyond the upper reaches of the earth. Will you have enough information about the planets and stars to understand what is being done? Will you be familiar with the problems which the experimenters will face?

When you have finished with the chapters in this unit, we think you will be able to look out into space, not only with wonder but with knowledge.

CHAPTER 4

OUR SUN AND ITS CHIPS IN SPACE

One night some years ago, people in the Middle Atlantic States tuned in to a radio program. What they heard was imaginary and meant to be entertaining. Actually, it frightened many of them out of a night's sleep. Some fled in panic from the cities toward Canada. Others got whatever weapons they could to defend their homes. The cause of this wild panic was a vivid description on the radio program of an imaginary attack on the New Jersey region by men from Mars.

Those of you who have had some work in science may know that if there are men living on Mars, no one has ever produced evidence of it. There has been some guessing but no proof. People throughout the ages have always wondered whether life exists on other planets as it does on earth.

Life occurs in many different forms. Microscopic living things have been discovered in the boiling waters of hot springs. William Beebe discovered peculiar creatures living in the cold dark waters hundreds of feet below the surface of the sea. If life can exist under these conditions, is it not reasonable to assume that it can exist in some form on some other planet in the sky?

You can answer this question for yourself when you learn what conditions exist on these planets. But first you will need to learn what conditions are necessary for the life of the plants and animals we know. Then you will need to know what sort of other bodies there are in our region of the sky and what conditions exist on them.

ONCE UPON A TIME

The people of ancient civilizations spent a good deal of time wondering about the different objects in the sky. A teacher named Aristarchus (ăr′ĭs-tär′kŭs) of Samos (sā′mŏs), an island in the Aegean Sea, said that the earth revolves around the sun. Aristarchus lived between 310 and 250 B.C.

Other teachers such as Ptolemy (tŏl′ĕ mĭ), 100–170 A.D., contradicted Aristarchus. They said the earth was the fixed center of the universe around which all else revolved. Because people like to think of their earth as the center of things, Ptolemy's idea became popular and was accepted for over a thousand years. About 1543, Nicholas Copernicus (kō pûr′nĭ kŭs), who was a priest, an astronomer, and a scholar, published a book setting forth ideas

based on his careful observations of the earth and its relations to other objects in space.

The book was published on May 24, 1543, just a few hours before Copernicus died. It thoroughly changed men's thinking about the universe. It set forth a theory that the sun rather than the earth was at the center of our solar system. Since that time, many men have studied the skies and much knowledge has been gained. Now we know very definitely that our home, the earth, is but a speck in the mighty ocean of space.

In this chapter we want to take you on an imaginary trip through space to show you something about the earth's particular place in it.

THE SUN AND ITS FAMILY

Let us imagine ourselves to be astronomers viewing the sun and the earth from another world somewhere out in space. Suppose we also have a telescope several thousand times more powerful than any telescope man has ever used. What will we see?

PLANETS AROUND A STAR

A quick glance will show that the earth is one of nine large bodies of assorted sizes traveling around the sun in nearly circular paths called *orbits* (Fig. 35). These nine large bodies are called planets. When a planet travels around the sun, it is said to be revolving about it. When a planet has made a complete turn in its orbit about the sun, it is said to have made one *revolution*. Each revolution completes a period in the life of the planet.

Only 36,000,000 miles from the sun is little Mercury, smallest of the planets. It is about 3,000 miles in diameter. Since Mercury revolves around the sun once every 88 days, its period is only 88 days in length. Beyond Mercury but nearly twice the distance from the sun (about 67,000,000 miles) is Venus. Venus is 7,580 miles in diameter and it takes about 225 days (its period) to complete one revolution around the sun. No doubt you know that the earth is the next planet beyond Venus; it is about 93,000,000 miles away from the sun. It completes one revolution around the sun in 365.25 days, its period (which we call one year), and it is 7,918 miles in diameter.

Beyond the earth you will find Mars, the reddish-looking planet. It is about 4,000 miles in diameter. Mars is about 141,500,000 miles from the sun. Its period is 687 days long.

Between Mars and the next big planet, Jupiter, is a swarm of tiny planets, none of which is larger than 488 miles in diameter. These are called the *planetoids* or *asteroids*. More than 1,500 have been discovered, but their number probably exceeds 50,000.

Jupiter, the largest of the planets, is 483,300,000 miles from the sun. It is 87,000 miles in diameter but spins around so rapidly that it completes its day in only 9 hours and 50 minutes. The time it needs to revolve around the sun (its period) is equal to 11.86 years on the earth.

The outermost planet easily visible to the unaided eye is Saturn. It is distinguished by its three rings of tiny moonlets which can be seen only with the help of a telescope (Fig. 36). Saturn is next to Jupiter in size—72,000 miles in diameter. Its distance from the sun is 886,000,000 miles and its period is equal to about 29.5 years on the earth.

Beyond Saturn are the three outer

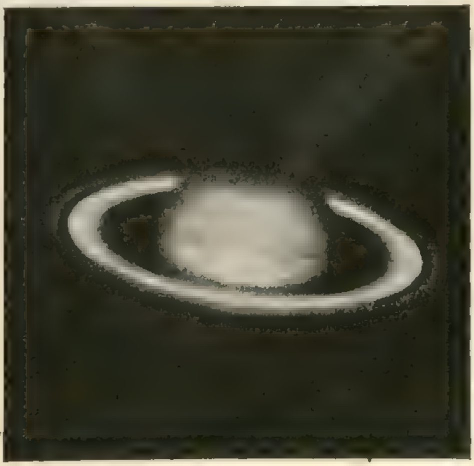
35 *Diagram of the solar system. The arrows show that all nine planets are revolving about the sun in the same direction. Which planet is farthest from the sun? Where is the earth?*

planets, Uranus, Neptune, and Pluto. These were discovered in 1781, 1846, and 1930, respectively. The stories behind each of these discoveries are fascinating accounts of scientific detective work. By all means read about them in the book entitled *Astronomy* listed on page 134.

Six of the nine planets have moons. In all there are thirty-one moons. Earth has one moon; Neptune and Mars have two each; Jupiter, twelve, Saturn, nine; and Uranus has five, the fifth one having been discovered in 1948.

The sun, its planets with their moons and rings, and its planetoids are known as the solar (sō′lẽr) system, or the sun's system. Of course there are other bodies in our solar system about which you may have heard. You will learn more about these bodies, such as

36 *A photograph of the planet Saturn taken through a telescope. Note the rings. Although only two rings are shown here, a third has been discovered. (American Museum of Natural History)*



meteors and comets, in the section "Astronomy as a Hobby" (p. 126).

OUR DAYTIME STAR

You may have guessed by now that just as the earth is not the only planet in the sky, so our sun is not the only sun in space. Actually each star is a sun, and our sun is a medium-sized star as stars go. Even so, our sun is more than a hundred times larger in diameter than the earth. The sun's diameter is approximately 864,000 miles. It would require more than a million earths to equal the volume of the sun.

The earth's distance from the sun varies from 91,500,000 miles in January to 94,500,000 miles in July but the figure usually mentioned is the average distance of 93,000,000 miles.

Until the seventeenth century, the sun was regarded by everyone as a uniform, fiery ball, but in 1610 Galileo (găl'ĭ lē'ō) discovered spots on its surface. Further observations revealed that these sunspots were moving across the sun's surface at different speeds. Later, scientists discovered that the sun is gaseous and not solid and that the sun rotates or spins.

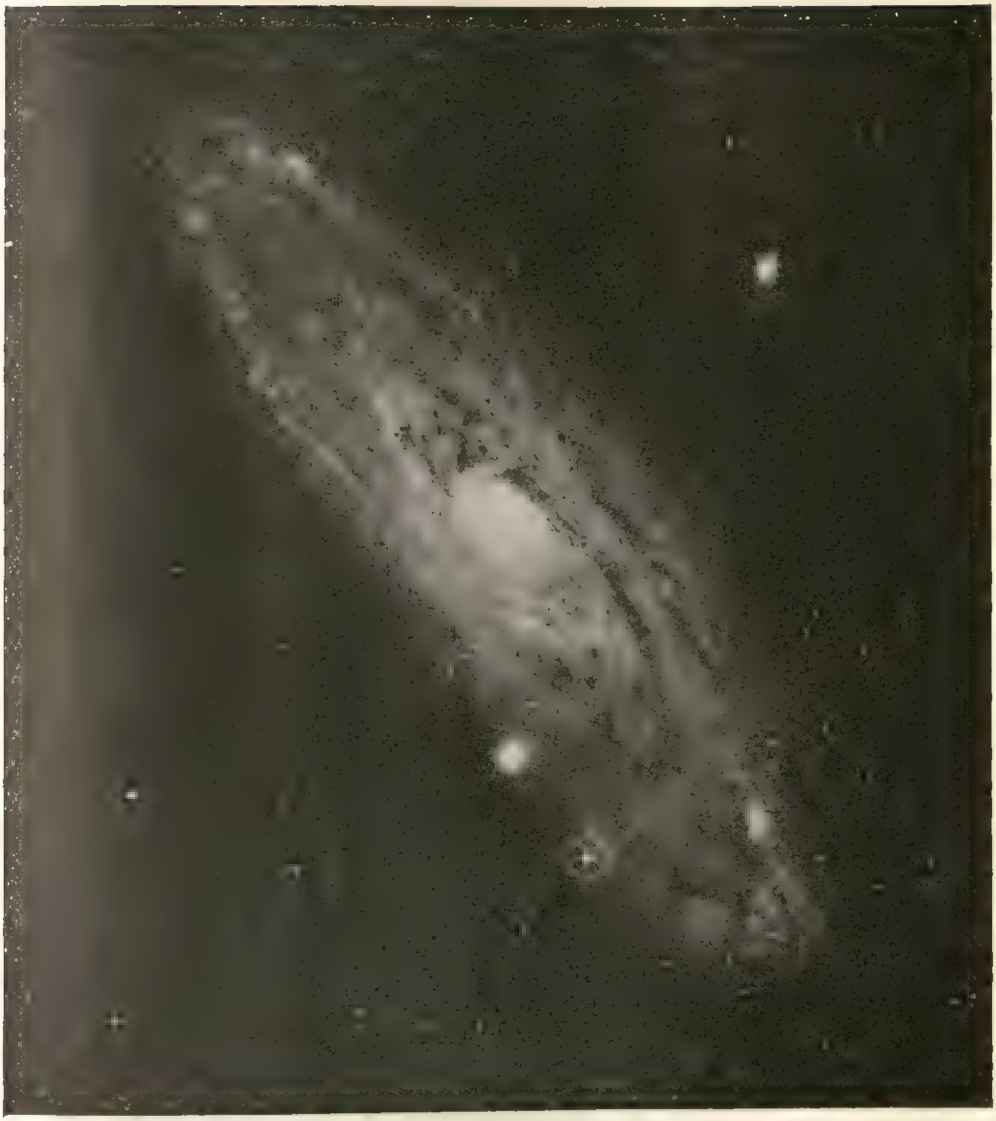
Although the sun is a globe of glowing gas, it is known to weigh 1.4 times as much as an equal volume of water. No one could come within 50,000,000 miles of it without burning up. The surface temperature of the sun is about 10,000° F. and its internal temperature is estimated at about 68,000,000° F. Only a tiny fraction of the heat radiated from the sun is received by each of the planets. The earth gets about one-billionth part of the sun's radiation.

SPEED OF LIGHT AS A MEASURE OF DISTANCE

Ordinary words for distance are meaningless when we compare the distance between sky objects. Astronomers know that the sun is about 93,000,000 miles away from the earth. But how far is 93,000,000 miles? Or the billions of miles that separate us from our nearest star, Proxima Centauri (prŏk'sĭ mȧ sĕn tô'rī). Scientists have another way of measuring "star" distances. They use the distance traveled by light in one year as a measure of distance.

Light travels at a speed of 186,284 miles per second. Traveling at this rate, light waves from the sun take about eight minutes to reach the earth. The light from the nearest star, Proxima Centauri, has to travel more than four years to reach the earth. Thus when you look at Proxima Centauri with a telescope, you actually see it as it was four years ago. The light sent out from it four years ago will have just reached you. Put it this way: If Proxima Centauri should become dark tonight, you would continue to see its light for four more years. You may say that Proxima Centauri is about four light-years or 275,000 times as far away from us as is our sun.

How far is four light-years away? Light traveling at 186,000 miles per second travels about 5,880,000,000,000 miles in a year. The distance of four light-years is, therefore, four times 5,880,000,000,000 or 23,520,000,000,000 miles. Our minds simply cannot grasp the meaning of such numbers. In any event, it is easier to say that the nearest star, Proxima Centauri, is four light-years away from us. Other stars may be 10, 100, 1,000 light-years away. So remember this unit for measuring, the light-year; you'll see it used often to suggest the relative distances between objects in the sky. For instance, some of the stars visible to the naked eye are estimated to be about 900,000 light-



37 *The Great Nebula of Andromeda as photographed through the telescope at the Lick Observatory. This galaxy is said to be the most distant object the naked eye can see. (American Museum of Natural History)*

years away from us, 100,000 times as far away as Sirius (sĭr′ĭ ŭs), the Dog Star, the brightest star in the sky. Sirius is only nine light-years away. It may be found in the constellation Canis Major (kā′nĭs mā′jēr), the Greater Dog, which follows the giant hunter Orion across the sky (p. 128).

A MODEL OF THE UNIVERSE

Sir James Jeans once said that there are probably as many stars as there are grains of sand on all the beaches of the world. Perhaps you are wondering what kind of universe can contain so many stars located at such great distances from each other and from us.

Dr. Donald Menzel, in his interesting little book, *Stars and Planets*, tries to represent the universe as an imaginary cubical building. Try to imagine this building with its foundations covering all of the United States and Canada. It would be 3,000 miles wide, 3,000 miles high, 3,000 miles long. One hundredth of an inch in this building is equal to three billion miles in the actual universe. We ourselves would be so tiny as to be invisible under the most powerful microscope. Where would our sun be in this building?

As we enter, Dr. Menzel tells us, the universe-building seems to be entirely empty. However, with a powerful telescope at the center of the floor we can see what appear to be swarms of gnats here and there. The largest of these swarms occupies no more space than the state of Rhode Island on a map of the United States and Canada. Yet each swarm is made up of trillions of stars, many as large as our sun or larger. Each swarm of stars is called a *galaxy* (găl′ăk sĭ). There are thousands of these galaxies in our building. One of them, in which the stars are arranged like the spinning pinwheel of a Roman candle, is shown in Fig. 37.

It is clear that the stars are not scattered evenly throughout our universe-building. They appear, as you remember, in large swarms called galaxies but between the galaxies there are great empty spaces. Where is our sun? It is in one of these galaxies called the Milky Way galaxy (Fig. 38). We find our sun in the Milky Way only because we are lucky and patient. For it is one of thirty billion or so stars in this galaxy. The stars in it are so numerous that they seem to form a milky road in the sky. The Milky Way is so large that if you were to count these stars at the rate of one a second, it would take you about a thousand years to complete the job even if you didn't stop to eat or sleep.

To grasp the size of the universe, you see, is an impossible task. Even professional astronomers find it impossible. Dr. Menzel's 3,000-mile building isn't a perfect comparison, for a building has top, bottom, and sides, but the universe has not, according to our best knowledge. How small is the speck on which you live! Our universe, mainly space, contains thousands of star islands or galaxies. Each galaxy is made up of millions upon millions of stars. Our sun, a star, is in one of these galaxies, the Milky Way galaxy. Our earth, one of nine planets circling around the sun, is but a speck of specks in a universe so vast that no one can truly conceive its vastness.

ORIGIN OF THE SOLAR SYSTEM

No matter how large our universe is, man is particularly interested in his own little corner—the earth. However, the earth didn't always exist. How did it come into being?

THE EARTH APPEARS

The earth did not come into existence by itself. According to all of the most widely accepted theories, it was born of the sun, together with the other planets. A theory, you remember, is a scientific explanation of facts that have been observed. It may be discarded if new facts are discovered which it does not explain. Scientists think that the planets in our solar system were born some two billion years ago. Here is one way the birth of our planet may have happened.

Somewhere in the universe was the

Milky Way galaxy. Somewhere in that galaxy our sun was speeding through space. Then something happened. No one knows whether there was a great explosion or a collision between our sun and another large body. Both possibilities have been suggested and discussed by scientists.

There are supporters of the explosion theory because so many stars (about 60 in the past 100 years) appear to explode. For instance, observers have seen a star suddenly become many times brighter, as if an explosion had occurred, and then gradually fade. Some scientists hold the theory that the fragments which exploding stars throw off may become planets like those of our own solar system.

One of the first explanations of the formation of our solar system was advanced by the French scientist, Laplace, in 1796. His ideas became known as the Laplace nebular hypothesis. He suggested that the sun and the planets developed from the gradual condensation of a large *nebula* (nĕb′ū lȧ). In the days of Laplace, the word nebula was used to describe any dim and distant object in the sky. Later research has shown that some nebulae are really clouds of gaseous material within our own galaxy. Other nebulae, like the Great Nebula of Andromeda (Fig. 37), are now thought to be vast systems of stars located far beyond the outermost limits of our own galaxy. These outer nebulae were called *island universes* by the great astronomer, Sir William Hershel.

It is entirely possible that within our own galaxy, or beyond in one of these outer nebulae, there may be other solar systems. And on some of the planets of these systems there may be life.

In 1909 the American scientists Moulton and Chamberlin advanced

38 *Our galaxy, the Milky Way, as it might look to an observer a million light-years away. At that distance the sun and the planets could not be distinguished.*

their own hypothesis. They thought that the solar system came from a special type of nebula, a spiral nebula (Fig. 39) like those which may be found in many parts of the sky. We know now, however, that a spiral nebula is made up of many stars. A spiral nebula is thought to be an island universe (p. 67).

These ideas were followed closely by the tidal theory of the Englishmen Jeans and Jeffreys. Their theory is that another sun passed close to ours and pulled a great deal of material away from it. This material, they believe, trailed out into space and formed two tremendous spiral arms composed of countless particles of all sizes (Fig. 39).

Gradually the larger particles swept up smaller gaseous fragments, until they reached the size of very small planets. In time, these small planets gathered up almost all the remaining material and became the major planets of the solar system. And, as you remember, a few thousand tiny planets called asteroids or planetoids still circle the sun between the planets Mars and Jupiter.

A newer theory of the birth of our solar system has been proposed by Dr. Fred Whipple of the Harvard Observatory. According to this theory, the sun, the earth, the other planets, and all the moons were born at approximately the same time from a great cloud of dust. His theory is supported by the fact that similar clouds of dust have been discovered in various parts of the sky. These dust clouds began to whirl. As they whirled, the various masses of material collected, the larger particles collecting the smaller ones, until the sun and its planets were formed.

The interesting fact that comes out of all these theories is their agreement on one point. That is the kinship of the earth and the sun. The theories indicate either that the earth came from the sun or that both the earth and the sun came from the same original cloud of dust.

Apparently all the planets, including the earth, came from the same source. On the earth more than a million different kinds of living things have developed. Knowing these two facts we may reasonably ask whether there is life on other planets. This question has fascinated men as few other questions have. What are the conditions necessary for life as we know it? Once we understand these conditions which make life possible on earth, we shall examine the other planets to see whether life can exist on them.

CONDITIONS FOR LIFE

There are known to be five main conditions required for life on this earth. If any one of these should change or disappear, all visible life would disappear or change greatly. All living things need a sufficient amount of oxygen, water, food, and proper temperature and pressure.

OXYGEN FOR LIFE

Oxygen belongs to a group of substances called gases. Oxygen makes up about one-fifth of all air; the remainder consists of a mixture of nitrogen and other gases. However, the air you breathe at the earth's surface contains more oxygen per cubic foot than the air five miles above the earth's surface. At 18,000 feet, or about 3½ miles above sea level, an airplane pilot would have to take two breaths to get as much oxygen into his lungs as in one breath at sea level. Rising to higher altitudes, fliers find it increasingly difficult to get enough oxygen to supply the body.

39 *Each of the theories represented has been advanced to explain the origin of the solar system. Although none of these theories has been universally accepted, all agree that the sun and the planets, including the earth, came from the same source.*

Therefore, the pilots and crews of high-flying bombers and pursuit planes now carry oxygen tanks and breathing masks.

Fish and other animals can live in water because it contains oxygen dissolved from the air. You have seen the gills of fish open and close as they draw water in through their mouths and let it pass out over their gills. In the gills, the oxygen in the water is absorbed into the blood of the fish, just as in your lungs oxygen of the air is absorbed into your blood.

Without oxygen in the atmosphere, all visible life as we know it would disappear from the earth. The atmosphere is a blanket of gases rising to a height of 500 miles or more above the earth's surface. Besides supplying oxygen, it absorbs some of the sun's heat and prevents the earth from being scorched during the day as well as from becoming too cold during the night.

WATER AND LIFE

It is estimated that two-thirds of your body is water. The water of the body is useful in digesting and transporting the foods you eat and is used to dissolve many substances in your body.

To replace the water you lose by wastes, most of you need to drink at least a quart of water each day. This water may come from milk or other foods but it cannot be sea water because the quantity of salts in sea water may cause death.

Water is one of the requirements of your everyday life. If you were without it, even for a day, you would realize how necessary it is. While the camel can store water for a week's supply and the cactus plant lives on stored-up water for months, even these two hardy specimens would perish with every other animal and plant if the water on the earth disappeared. Body activities would cease if water were not supplied to the tissues.

FOOD AND LIFE

The foods you eat furnish you with the energy to work and play. They must furnish you with sufficient material to replace that which you are constantly wearing out through exercise. They must furnish you with everything you need for proper growth.

Because of the constant need for food, life is limited to regions where food can be obtained. There are some animals, like cows, horses, and sheep, that can eat only plants; they live where they can easily get grass or similar food. Then there are animals that are meat eaters, such as the lion, tiger, and wolf. Their homes are near or within the places where other animals live. Lastly there are those animals, including man, that eat both plants and meat. But man is less tied down by his food problem than other animals because he has developed means of transportation and food preservation. By taking his food with him or having it transported to him, man has been able to range over the face of the earth.

TEMPERATURE AND LIFE

A healthy human body stays at a temperature of about 98.6° Fahrenheit. Man can live only where he can maintain his body at that temperature.

On the earth, altitude and location produce wide variations in temperature. Higher spots on the earth, such as the upper slopes of Mount Everest, are subject to such bad storms and low temperatures that life cannot exist there permanently. In Siberia, near the Arctic Circle, a temperature of more than 100° F. below zero has been

40 *A photograph made with the Hale 200-inch telescope at Mt. Palomar, California, January, 1949. Notice the gaseous nebula in the center which is only a few thousand light-years away from the earth but within our galaxy. The Hale telescope has photographed other nebulae a thousand million light-years away, thus extending our knowledge of the universe tremendously. (Mt. Wilson-Palomar Observatories)*

recorded. In Death Valley in California, a temperature of 149° F. above zero has been recorded. With suitable preparations, human life can exist for a short time in temperatures like these. However, there are extremes beyond which human life is not possible (Fig. 41).

The lowest possible temperature is 459° F. below zero. At that point no life would remain on the earth. Even the air would be a solid, frozen mass. On the other hand, at high temperatures solid things turn into gases or liquids. The temperature of a gas flame like that of the Bunsen burner may reach 1500° F.; iron melts at 1700° F.

The bodies of all living things have within them materials similar to those in the white of an egg. These materials are called proteins (prō′tē ĭnz). In order to make a poached egg, you heat the water to boiling or 212° F., then break the egg into the water. The liquid white of the egg immediately becomes firm and white, and the yellow yolk thickens. The proteins in your body would change much as the egg does if you were exposed to a temperature above 158° F.

On the other hand, if human beings were entirely unprotected, their bodies would become icelike or solid at 23° F., or just nine degrees below the freezing point of water. By means of clothing, heating, and cooling systems men can live in extreme temperatures, but there are temperature limits beyond which no living thing can survive.

PRESSURE AND LIFE

Man makes use of pressure. By exerting pressure against a brake pedal in an automobile or truck, the driver can bring tons of moving steel to a stop. Air forced against a reservoir of oil or water raises elevators. The barber with a push of his hand or foot raises you in a chair by the same method. The pressure of air in the tires of large planes allows them to land gently.

You yourself are under constant pressure. The weight of air presses on you from all directions with a pressure equal to 14.7 pounds per square inch at sea level. What keeps you from collapsing? There is a pressure inside your body partly maintained by air and body fluids. This body pressure pushes outward so that the pressures inside and outside the body are equalized.

Animals that live in water withstand a greater pressure than do animals that live in air. A column of water only 34 feet in height exerts the same pressure all over their bodies as the weight of 500 miles of air does on your body. A fish living one mile down in the ocean withstands a pressure of over one ton per square inch. Yet this great pressure outside is also equalized by pressure within the fish's body, and life in the ocean depths is as unaffected by pressure of water as you are by the pressure of air. When a fish is being hauled up quickly from the ocean depths, its body swells as the greater pressure inside its body meets the decreasing pressure of water nearer the surface.

To withstand the pressure of water, even at short distances below the surface, divers have to wear suits into which air is pumped at a pressure equal to the pressure of the water. They breathe in this air which changes their inside body pressure and consequently, like the fish, they cannot be brought up to the surface rapidly. If a diver works for some time in deep water, he must be brought to the surface slowly if he is not to suffer any ill effects. During the time when he is being brought to the surface the pressure inside the body is gradually adjusted to the changing out-

41 *The people in this experimental chamber are testing airplane instruments under high-altitude conditions. Why are they dressed so peculiarly?* (*Boeing Aircraft Company*)

side pressure at higher levels. Read Commander Ellsberg's book, *On the Bottom*, to get an idea of how pressure affects divers.

Changing pressures on the earth's surface slightly affect travelers. "Bubbles" that hum in your ears as you ride up and down steep slopes or on elevators are the attempt your body makes to equalize its pressure inside with the changing pressure of air outside. Designers of future transport planes that will fly high above the earth have planned to have the passengers sealed in, breathing air at the same pressure as that on the earth's surface.

These then are the conditions necessary for life. Every animal and plant on earth needs sufficient amounts of oxygen, water, food, and the proper temperature and pressure. Whether the kinds of living things we find on earth can survive on other planets depends on whether these conditions for life are present there.

CONDITIONS ON OTHER PLANETS

What are the conditions scientists have been able to discover on other planets?

Mercury is the planet nearest to the sun. It has no atmosphere. As it revolves, it always presents the same side to the sun. The temperature of the

42 *Note the size of the south polar icecap in this photograph of the planet Mars. What do changes in the size of this icecap tell us about the climate on Mars? (American Museum of Natural History)*

sunlit side is about 700° F., which is above the melting point of lead and 500° F. above the boiling point of water. Its dark side is too cold to measure but is probably close to −459° F. below zero. Can you imagine any form of life capable of survival under such conditions?

Venus is the planet which in several respects is most similar to the earth. Its atmosphere is so full of clouds that no one has ever been able to glimpse its surface. We do not know the composition of these clouds and we cannot find out what is below them. In the atmosphere above the clouds, no water vapor or oxygen has been detected. However, in the highest layers of this atmosphere, great amounts of carbon dioxide gas have been detected. If the same concentration of this gas exists near the surface of Venus, life as we know it at present could not exist there. The temperature of the upper atmosphere of Venus is about −50° F. which is not far below the temperature of the upper atmosphere on our earth.

Mars is known for its red color (Fig. 42). In its polar regions there are white caps which change in area during the year. Some astronomers believe these caps are snow and ice or frost. Through the telescope you can see a network of dark lines which are called the canals of Mars. Few scientists believe these are real canals. The seasons on Mars are about the same as on the earth. But they are about twice as long. Although Mars has no oceans, it appears to have some water present because of the changing size of the polar caps. Mars receives from the sun only four-ninths as much heat as the earth receives. The atmosphere of Mars is very thin and its temperature seldom rises above 0° C. or 32° F. and then only a few degrees in the summer season.

The amount of oxygen in the atmosphere of Mars is very small. Can life exist under such circumstances? The famous astronomer, Lowell, argued that the seasonal changes in color and the strange canals are evidence of life and intelligence at work. Few astronomers are ready to accept Lowell's theory but they will admit that there is no absolute evidence against it.

Jupiter, Saturn, Uranus, and *Neptune* are giant planets much larger than the earth. *Pluto,* another planet, farthest away from the sun, is much smaller. Little is known about Pluto, but it is so far away from the sun that its temperature is surely near −400° F. The low temperature alone would argue convincingly against the possibility of life on any of these planets. Jupiter is the warmest of the group of giant planets

with a temperature of $-202°$ F. The atmospheres of the giant planets have been found to contain two poisonous gases either of which would destroy all earthly forms of life. The gases are ammonia and methane (mĕth′ān). Methane is the "firedamp" so dangerous to miners. Ammonia needs no identification. It is well known in every home and is also used in ice factories.

Now that you have these facts, would you say that life exists on other planets? Most scientists would say that if life exists, it has the best chance of surviving on Mars and Venus. Can you see why from the facts you have just read? It is believed that if life has developed on these planets, it may not be like ours at all. We shall have to wait for direct evidence—the reports of the first earth men who reach these planets. We shall want actual specimens and photographs. Till then we can only theorize.

THE SUN AND THE EARTH

We need not theorize about the conditions which make life possible on earth. We know that this life depends upon the light and heat we get from the sun.

Probably you have not realized that the length of the seasons depends on the position of the earth relative to the sun and also on its motion around the sun. So does our system of telling time. Seasonal changes in temperature occur because the earth's position in relation to the sun changes throughout the year. Just to give you an idea of the way the sun really governs our lives, do this experiment yourself.

THE EARTH'S SHARE OF SUNLIGHT

Take a large ball or a globe (the earth), a small electric light bulb (the sun), and a piece of chalk, and go into a darkened room.

Light the bulb. Hold the ball in its rays. Notice that no matter how you hold it, one half of the ball is always in darkness, the other half always in the light. Remember that the sun represented by your light bulb gives out light and heat in all directions at the same time. The entire earth catches only a billionth of the energy released by the sun. How fortunate this is! Can you imagine what would happen if we were to receive two or three times as much energy from the sun or only half as much? If we got two or three times as much, we should be burned to a crisp. If we got only half, we should freeze.

Hold the ball about a foot away from the light bulb. Don't move the ball. Place the bulb of an air thermometer between the ball and the light bulb. Place another air thermometer against the darkened side of the ball. Observe the difference in temperature. The situation is similar to what would happen if the same side of the earth were always turned toward the sun. The lighted side would be too hot for most forms of life. The dark side would be too cold. Actually, the difference in temperature between the two sides would be far greater than in this simple experiment. The difference might be like that found on the planet Mercury (p. 74).

SUNLIGHT AND SHADOWS

Fortunately for living things, the earth is not motionless. It is easy to imitate two of its motions. Place the bulb (sun) on a table. Carry the ball representing the earth all the way around the lamp. The earth takes about $365\frac{1}{4}$ days to make this kind of journey around the sun. We call this journey a *revolution*. Our calendar year is based

upon the time consumed in this revolution. But that is only one motion that the earth makes.

Now put a chalk mark on the side of the ball nearest to you. This chalk mark represents the place where you live. Continue the revolution around the lamp, but this time twist the ball with your fingers at the same time. We call this motion *rotation*. It takes the earth 24 hours to rotate once. This rotation determines the length of a calendar day. While making 365¼ rotations (days), the earth revolves once around the sun. Notice that the chalk mark you made on the ball is carried by the earth from the lighted side to the dark side and back again into the light. When the chalk mark is in light, it is in "daytime"; when it is in the dark, it is in "nighttime" (Fig. 44).

DAY AND NIGHT

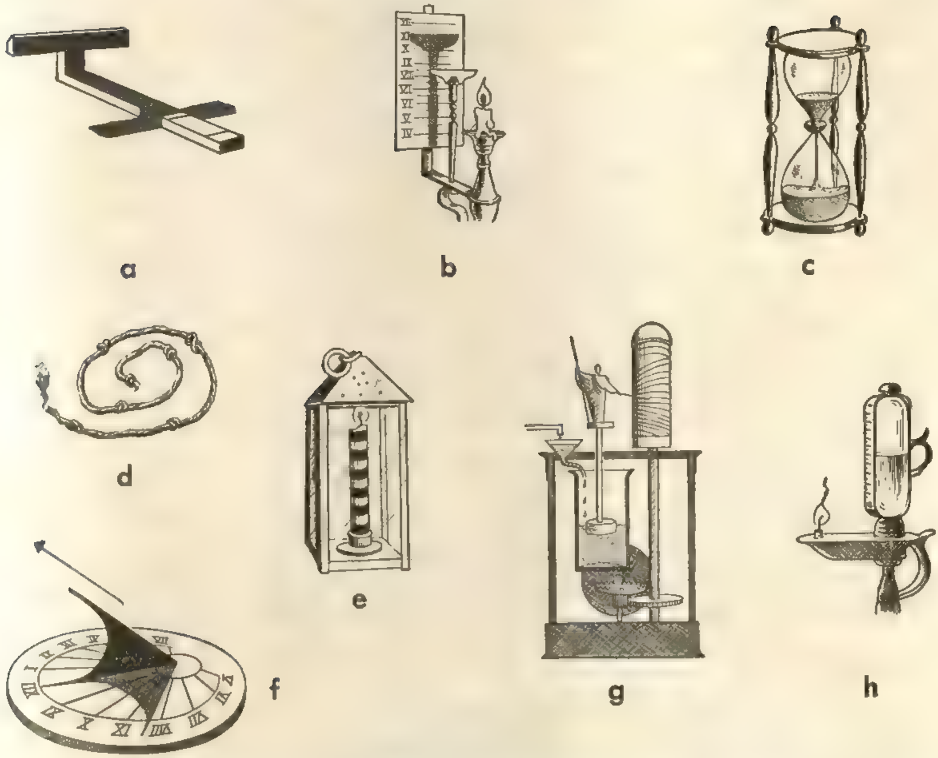
Whatever other changes may take place in your immediate surroundings, there are two changes on the earth's surface that you can always be sure of. Day always changes into night and night always changes into day. This is because the earth is round and because it rotates. However, the sun's light can strike only one half of the earth at any moment of the earth's rotation. As the earth turns from west to east, new points on the earth's surface come into the light of the sun. If you were in Chicago and looked east at early dawn, you would see the sun appearing as the city of Chicago turned eastward. At evening, if you were to look toward the west, you would see the sun disappear as Chicago turned farther eastward. Night and day and sunset and sunrise are due to the earth's rotation. You can picture rotation best by turning a globe of the earth on its central axis. Of course, there is no real axis in the earth such as you find on a classroom globe. However, it is well to think that the earth actually spins as if an axis, or imaginary line, extended through its center from the North Pole to the South Pole. You may think of the earth spinning as if it were a top.

DIFFERENT LENGTHS OF DAYS AND NIGHTS

Have you ever wondered why the globe at school or in your home is tipped away from a vertical position? Scientists have found that the earth is tipped on its axis like a leaning top. Globes representing the earth are tipped in the same way to show that this is the position of the earth as it spins and moves around the sun. The earth's axis is tilted at an angle of 23½° (Fig. 44).

The tipping of the earth is responsible for the different lengths of days in fall, winter, spring, and summer. As the earth revolves in its orbit around the sun, the South Pole leans toward the sun during part of the year. This causes more sunlight and heat to be given to the southern portion of the earth. Gradually the earth moves around to the other side of the sun. In this position, the North Pole leans toward the sun and the northern portion receives more sunlight and heat. The hours of daylight increase on that part of the earth that receives more sunlight; they grow shorter where the earth receives less sunlight. This partly explains why it is winter in the Southern Hemisphere when it is summer in the Northern Hemisphere.

Since the length of the day and of the different seasons is mainly responsible for weather, you will find a full explanation of daily and seasonal change in Unit III, "Understanding the Earth's Weather." Right now we are interested in the fact that the rotation of the



43 *Telling time in bygone days: (a) Egyptian shadow scale or sundial, (b) French candle clock, (c) medieval sand glass, (d) Oriental burning rope clock, (e) English time candle, (f) sundial, (g) Roman water clock, (h) Dutch oil lamp clock. How could you use each "clock" to tell time?*

earth gives us day and night, and that the earth's revolution around the sun determines the amount of daylight and the seasons. In addition, the relation of earth and sun also determines the way in which we tell time.

TIME IN 1500 B.C.

The earliest record of telling time has come to us from King Thutmosis (thŭt-mō′sĭs) of Egypt, who reigned in 1500 B.C. King Thutmosis fashioned a flat, narrow board about seven feet long and six inches wide. To one end he attached an upright board one foot in height (Fig. 43). As he pointed the upright board in the direction of the sun, the shadow it formed fell on the bottom board. When the sun came up in the morning, he made a mark on the board where the shadow struck. Keeping the board pointed toward the sun, he made other marks on the board to show how the shadow changed its position during the day. In this way, the early Egyptians could tell the time of day.

Thutmosis had made the first sundial. Today you can see modern sundials as ornaments in gardens and parks, telling time by the shadow of a pointer when the sun shines (Fig. 43). Of course, you

have watches and clocks to tell time today, whether the sun shines or not, but the Egyptians had only their crude sundials. They learned to make appointments by saying they would meet as the shadow of the sun reached or went half past a certain mark on the bottom of the board.

Later, because Egyptians liked to count by twelves, they divided the day into 12 marks. They divided the night into 12 marks also by measuring what appeared to be the movement of certain stars. Thus the total marks in day and night were 24. Our own 24-hour day is based on the old Egyptian measurement of time.

Today we do not depend on sundials to tell us the time of day, but we do depend on the sun.

HOURS OF THE DAY

Before you learn about our own methods of keeping time you will need to find out what lines of longitude, or *meridians*, are. Have you ever sliced an orange right through the middle? How would you slice an orange in order to get 360 equal pieces? Of course you would keep dividing the new pieces until you got the required number. A line of longitude is represented on the earth by an imaginary line drawn from the North to the South Pole, just as your knife might cut an orange from the top to the bottom (Fig. 44). If you should draw 360 of these lines equally spaced around the earth from the North Pole to the South Pole, each line would represent one degree of longitude.

Today these meridians or lines of longitude are used to give us our hours. In 1884 at the Washington Meridian Conference, the civilized world agreed to establish standard time, based on lines of longitude 15 degrees apart. You can readily see that there would be 24 of these meridians 15 degrees apart making up 360 degree divisions of the earth. In other words, 360 divided by 24 yields 15. As the earth turns on its axis, it takes one hour for it to turn 15 degrees past any given point. Therefore one hour of time can be said to equal 15 degrees of longitude. The 24-mark day of the ancient Egyptians was useful, for it takes 24 hours for the earth to make a complete rotation of 360 degrees, 15 degrees every hour.

The meridian passing through Greenwich, England is taken as 0° longitude. All meridians east of Greenwich to longitude 180° are called east longitude; all meridians west of Greenwich to longitude 180° are called west longitude (Fig. 44). Philadelphia is at 75° west longitude, that is, five meridians west of Greenwich. There is a difference, therefore, of five hours between the clocks of Philadelphia and Greenwich. Since Philadelphia is always moving eastward to the points that Greenwich has occupied, Philadelphia clocks are always five hours behind those of Greenwich. In other words, when it is two in the morning in Greenwich, England, it is five hours before then or nine at night in Philadelphia (Fig. 44).

TIME ZONES IN THE UNITED STATES

There are four 15-degree meridians crossing the United States; therefore there are four time zones. On the map (Fig. 44), you will notice that the time zones do not follow meridian lines. That is because large cities and railroads were not built to conform with meridians. Therefore, the lines of time zones are irregular to agree with the convenience of large numbers of people who are affected by time zoning.

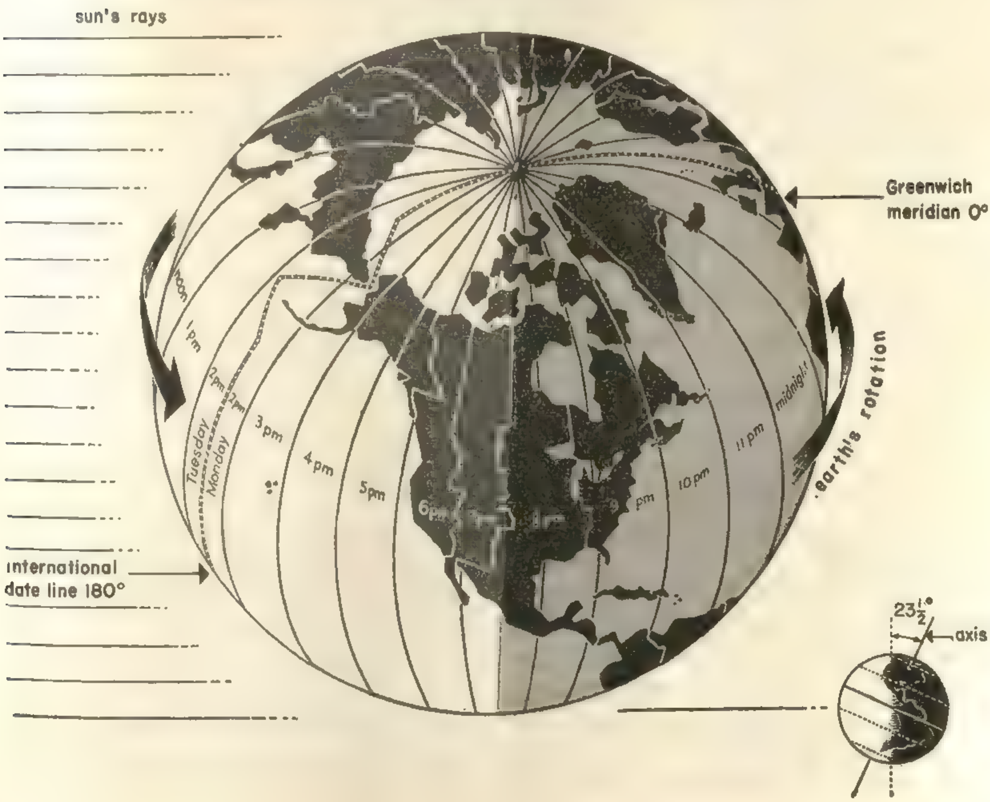
When you study the map, you will notice that Central Standard Time is

one hour earlier than Eastern Standard Time. The next division is Mountain Standard Time, which is one hour earlier than Central. The last is Pacific Standard Time, which is one hour earlier than Mountain Time. These time zones affect radio programs and also people who are traveling across the United States. The radio receives messages from the announcer almost the instant he speaks. In New York, when it is three o'clock in the afternoon Eastern Standard Time, it is noon Pacific Standard Time in California. That is why people in California may be having lunch while listening to an afternoon broadcast from New York. People who travel westward from New York set their watches back one hour when they get to the boundary of each zone. Traveling eastward, people set their watches ahead when they pass the boundary of each time zone.

THE INTERNATIONAL DATE LINE

You have now seen that each 15-degree meridian represents one hour as the earth turns or rotates on its axis. Suppose you start from New York and keep traveling westward, setting your

44 *Twice a year (at the equinoxes) the entire earth, as shown here, has twelve hours of daylight and twelve hours of darkness. The diagram also shows the time zones in the United States and the international date line. What should you do to your watch when going from New York to San Francisco? when crossing the date line?*



watch back one hour as you pass through each time zone of the United States and continue to set your watch back for each 15-degree meridian as you travel across the Pacific, across Asia, Europe, and finally come back to your starting point. If you could do this in one day, you would find that 24 hours or one full day would have been gained on the calendar. In other words, if you started your journey on Tuesday at 7 A.M. and set your watch back for each 15-degree meridian as you swiftly sped along on your day's journey, you would naturally expect to arrive at 7 A.M. Tuesday back at your starting point!

Is it possible to gain a day in your life? An *international date line* was set up by the Washington Meridian Conference of 1884. Passing between Alaska and Siberia and through the Pacific, this imaginary line is placed where it inconveniences few people. This is the 180th degree of longitude (Fig. 44). Greenwich, England is on the other side of the earth at 0° longitude. Actually, the international date line zigzags slightly, as you will see in Fig. 44. This is due to an attempt to avoid any land area on the 180th meridian; it was thought best to change the date only when the "date line" was crossed on water.

Nations agree that as you travel westward you gain one full day when you cross this date line. As you travel eastward across the Pacific you must subtract one day when you cross this line. Thus if it is 11 A.M. Tuesday when you reach this date line, going westward, it will be 11 A.M. Wednesday after you cross it. Traveling to the United States from China, if it is 11 A.M. Tuesday when you reach this line, it will be 11 A.M. Monday when you cross it. In this way, trade and commerce with far eastern or western points can agree with the days of the standard calendar.

CHANGES IN TIME

In the United States, there have been changes made by federal or state laws to advance standard time in the four time zones by one hour. This is called Daylight Saving Time. It is for the purpose of giving workers more daylight on their jobs and furnishing more light for recreation or work about the house afterwards. It also saves electric power that would be required to furnish light in the later afternoon. Ordinarily, a person goes to work when the sun's light in his time zone is one to two hours above the horizon. With Daylight Saving Time, a person may go to work when it is still dark. When he gets home, he has more daylight than he would have had under Standard Time.

THE MODERN CALENDAR

Long ago the Egyptians knew that the year was 365¼ days long. However, the Romans, who learned this fact from the Egyptians, had great difficulty in reckoning time in a year that ended in a fraction of a day. In 46 B.C., a great Roman emperor, Julius Caesar, laid the foundation of our modern calendar. He proclaimed that instead of 365¼ days, a year should be 365 days long. However, that left ¼ day a year which had to be accounted for. Caesar decided that every fourth year a day should be added to take care of the four extra ¼ days (one ¼ day for each of the four years). Julius Caesar further ordered that the extra day should be added to the second month of the year, or February. That is why Leap Year comes every fourth year with an extra day in February.

But 365 days a year is a large num-

THE WORLD CALENDAR
OF EQUAL QUARTERS

FIRST QUARTER		
JANUARY	FEBRUARY	MARCH
SECOND QUARTER		
APRIL	MAY	JUNE **
THIRD QUARTER		
JULY	AUGUST	SEPTEMBER
FOURTH QUARTER		
OCTOBER	NOVEMBER	DECEMBER*

S	M	T	W	T	F	S	S	M	T	W	T	F	S	S	M	T	W	T	F	S
1	2	3	4	5	6	7				1	2	3	4						1	2
8	9	10	11	12	13	14	5	6	7	8	9	10	11	3	4	5	6	7	8	9
15	16	17	18	19	20	21	12	13	14	15	16	17	18	10	11	12	13	14	15	16
22	23	24	25	26	27	28	19	20	21	22	23	24	25	17	18	19	20	21	22	23
29	30	31					26	27	28	29	30			24	25	26	27	28	29	30
																				* W

* Worldsday (a World Holiday), W or 31 December (365th day), follows 30 December every year.
** The Leapyear Day (another World Holiday), W or 31 June follows 30 June in leap years.

THE THIRTEEN MONTH CALENDAR

EVERY MONTH						
S	M	T	W	T	F	S
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

Every month the same.
Extra days may be provided as above.

45 *Compare these calendars with the one we now use. In the World Calendar of Equal Quarters (top), notice that each quarter has 91 days, making a a total of 364 days. This calendar provides for the 365th day by placing it at the end of December. Leapyear Day is added every fourth year, as in our present calender, but it is placed at the end of June instead of February.*

ber. Would you remember an appointment, say 36 days from now, unless you marked the days off, one by one? In Caesar's time, people had already used the moon as a basis for their division of the year into smaller periods. They noticed that the moon seemed round or full about 12 times a year. These divisions of the year were later called months. As the calendar was developed, each month came to have its characteristic number of days.

In Fig. 45 you will find a comparison of two calendars. Which is the better one? Which do you think should be the calendar of the future? The calendars of the future like those of the past will be based on two facts. First, the earth rotates on its axis; this rotation is responsible for the length of the day and hour. Second, the earth also revolves around the sun; this revolution is responsible for the different lengths of day and night, for the seasons, and for the length of the year.

TWO BILLION YEARS AGO TO NOW

Two billion years or more ago, the solar system and the earth were born. On this earth more than one million kinds of living things have developed. One of these living things is man.

Now two billions years or so later, there are more than two billion people on earth, and man is on the road toward developing the earth's resources for human welfare. He is using science for effective living.

GOING FURTHER

1 *Using your watch as a compass.* When you do this experiment, be sure that the sun is shining. Hold the watch face up and place it on a horizontal surface. Point the hour hand toward the sun. Now place a small stick or a toothpick in such a way that it will divide the number of minutes on the dial of the watch between the hour hand and the number 12 into two equal parts. The small stick should lie across the center of the watch. It will point approximately north. For example, if the hour hand is at 10 A.M., your stick will be laid across the numbers 11

and 5. The number 5 will indicate north. Remember the hour hand must point toward the sun.

2 *Making a sundial.* A sundial is simple to construct. Write to Superintendent of Documents, Washington, D.C. Ask for Bureau of Standards Circular 402, "Sundials," 1933 (5 cents). This pamphlet will give you complete details.

3 *Models of ancient "clocks."* Make models of some ancient devices for telling time. Illustrations are to be found in Fig. 43.

4 *Words are ideas.* Can you use these words in a sentence which will give their meaning? Use the glossary.

asteroids	universe
Copernicus	Venus
Jupiter	revolution
galaxy	axis
Pluto	Saturn
Neptune	Uranus
star	Mars
Mercury	rotation
Milky Way	day
nebular hypothesis	hour
explosion theory	longitude
tidal theory	Greenwich
dust cloud theory	international
Ptolemy	date line

5 *Put on your thinking cap.*

1. If it were suddenly announced that life had been discovered on Venus or Mars, what facts would you need before you would believe the report to be true?

2. Life on the earth might be greatly changed if only a few conditions were changed slightly. Explain this statement.

3. What arguments may be advanced for and against the adoption of a new calendar such as the World Calendar? Consult the World Almanac for information.

6 *Test yourself.* In your notebook, complete the following sentences with the correct word or phrase. Do not mark this book.

1. Most authorities agree that the solar system is at least ...... years old.

2. According to the ...... Theory, when the earth was born as many as ...... planets were formed and also thousands of ......, whose orbits lie between the orbits of the planets Mars and ....

3. ...... of the planets have moons.

4. In all, there are ...... known moons.

5. The moon, the planets, and even the sun, which is on the average about ...... miles away from us, are our nearest neighbors in the sky.

6. The stars are so far away we have to measure their distances by ....

7. According to this way of measuring distances, the nearest star beyond our sun is ...... light-years away from us.

8. Our solar system belongs in the swarm of stars called the ....

9. Our present ideas about the solar system are based on the work of .... Before him, the ...... was considered the center of the universe.

7 *Adding to your library.*

1. *The Birth and Death of the Sun* by George Gamow, Pelican Books, 1945. An exciting description of the possible origin of the sun and its relation to us.

2. *Telling Time Throughout the Centuries* published by the American Council on Education, Washington, D.C. It gives an excellent summary on this subject.

3. Send for the quarterly magazine of the World Calendar Association, 630 Fifth Avenue, New York 20, N.Y. In addition to articles on calendar reform, it contains many interesting facts about astronomy and astronomers. The publication is called *The Journal of Calendar Reform.* It is free.

8 *Men and women wanted.* Do you want a hobby? Perhaps an idea for a future vocation? Read "Astronomy as a Hobby," page 126.

CHAPTER 5

OUR SATELLITE—THE MOON

Ever since Jules Verne wrote his famous tales *From the Earth to the Moon* and *Round the Moon*, the idea of visiting the moon has fascinated many people. Even with the possibility of long-range rockets it is still a dream, but not quite as improbable as it was in the time of Jules Verne. The experiments of Professor Zwicky (p. 59) and those of other scientists may give us the information needed for making the first trip.

What sort of heavenly body is this nearest neighbor in the sky? What might we find on a trip to the moon?

LOOKING AT THE MOON

Your target for tonight is the moon. It is an excellent object for amateur observers. In the first place, it is close to the earth—only about 240,000 miles on the average, and at times as near as 220,000 miles. Also the moon is fairly large as moons go—2,160 miles in diameter or approximately one-quarter of the earth's 7,918 miles. Nevertheless, the moon is no easy target to hit with a rocket.

The scientist who aims a rocket at the moon must be able to calculate the path of the rocket and also the path of the moon during the time the rocket is in flight. Of these two tasks, the second is the easier. Astronomers have calculated the exact path of the moon. They can tell you to a fraction of a second just where the moon will be in the sky at any time.

JOURNEY OF THE MOON

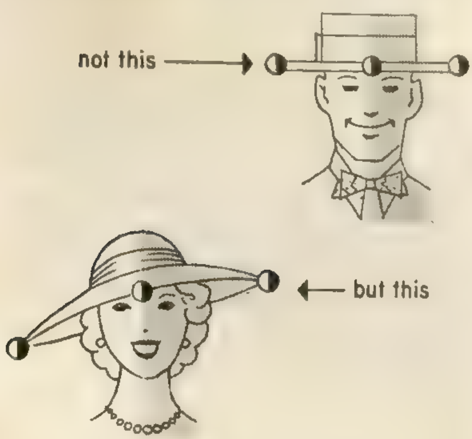
The easiest way to "see" the way the moon is traveling about the earth is to do a couple of simple stunts. One is to get a hat with a brim that can be adjusted so it will encircle the crown at an angle of about five degrees (Fig. 46). If you think of the crown as the earth, the circle made by the brim is the moon's orbit. As you remember, an orbit is the path an object in the sky takes around another object. The moon's orbit is its path around the earth.

Imagine yourself holding a ball at the edge of the brim and at your eye level as in Fig. 46. The orbit of the moon around the earth is similar to the path of the ball you are holding as you move it around the edge of the brim. The entire trip takes the moon about $29\frac{1}{2}$ days.

There is another peculiar thing about the journey of the moon around the earth. Its spinning on its axis is synchronized with its traveling on its orbit so that the same side of the moon is always turned toward the earth. (Actually, we can see at one time or another about 59% of the moon's surface.)

It is not difficult to demonstrate this idea. Place a chair in the center of the room. It will represent the earth. You are the moon. Face the chair. Continue to face it all the time while you circle completely around it. Notice that you have actually faced all four of the walls of the room during your trip. Facing all four walls is equal to rotating once. You, therefore, rotated once while you revolved once around the chair. The moon takes a month (originally called a "moonth") to make the same kind of trip.

If you were able to see the moon and the earth from another planet how would they appear to move? Look at Fig. 47. It shows how the combined motions of the earth and the moon might look to an observer in space.



46 *The moon's orbit around the earth, like the brim of the lady's hat, is tilted at an angle of about five degrees.*

How does the motion of the moon appear to us on the earth? There is only one satisfactory way to answer that question. Watch the moon for a month. During one night it will appear to rise in the east and set in the west. Notice that on the average it rises and sets about 51 minutes later than it did the day before. You may also notice that at a given time, the moon has moved toward the east from one day to the next. This may be noted by checking the position of the moon against the pattern of the stars.

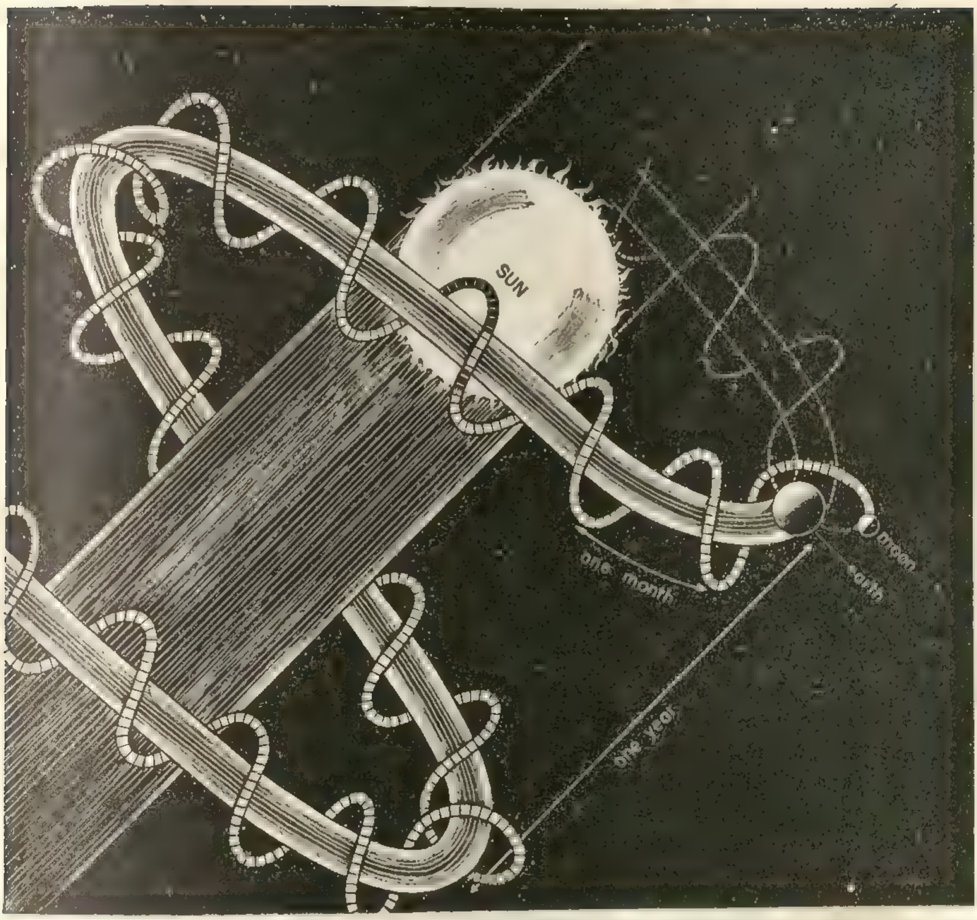
THE MOON'S FACE AS WE SEE IT

Twice during a month the moon is nearly in line with the sun and the earth. At two other times, it is at right angles to a line between the earth and the sun (Fig. 48). As it changes its position relative to us and to the sun, the moon changes its appearance. These changes in appearance are known as the *phases* of the moon. Here is how you can demonstrate these phases in your own home.

Turn on a bright light without a lamp shade. Hold a ball at arm's length. Now turn slowly on your heel. If the lamp is bright enough, the ball may become almost invisible when you hold the ball toward the lamp. This corresponds to the new moon phase of the moon. At this time, the moon is difficult to see. The side turned toward us is unlighted at this phase (Fig. 48).

As the angle between the sun, earth, and moon increases, a thin crescent moon appears. At this stage, it is closest to the sun. The cusps or "horns" of the crescent moon are always turned away from the sun (Fig. 49).

The entire face or disk of the moon is visible when the moon is farthest from the sun, because then the sun lights that portion of the moon facing us. This is



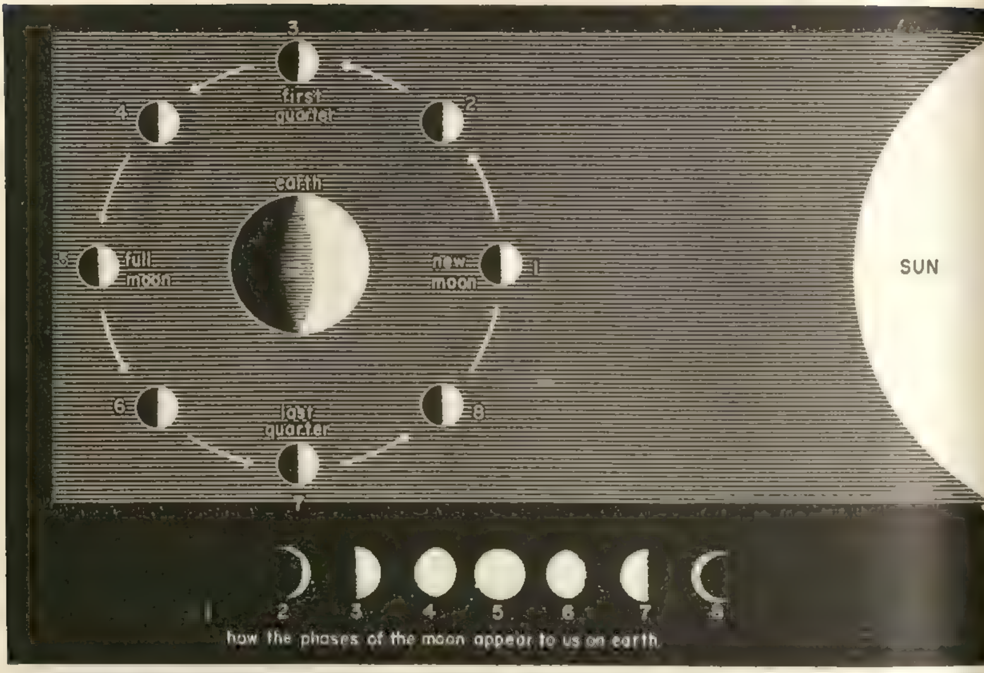
47 *This diagram (not drawn to scale) shows the motions of the sun, the earth, and the moon as they would appear to an observer in space. The sun moves forward, the earth moves around the sun, and the moon moves around the earth.*

the familiar full moon phase. At this time, the moon's landscape is clearly outlined. Its mountains, plains, and craters may be seen easily in photographs such as the one in the center of Fig. 49. The mountains cast large shadows. The pattern on the moon caused by dark and light areas appears to some as the face of a man.

After the full moon, the line separating the dark half of the moon from the sunlit half slowly recrosses the surface of the moon. The size of the lighted area grows smaller or wanes. The shape once more becomes a crescent. As the moon rotates around the earth, therefore, it reflects different amounts of sunlight in our direction. Photographs of these phases are shown in Fig. 49. All these changes in the moon's appearance take approximately one month.

ON THE MOON

If a rocket is ever built that is capable of taking a passenger to the moon, it will have to be built to withstand a



48 *The relationship of the moon to sun and earth. One half of the earth and one half of the moon are always lighted by the sun's rays. How much of the lighted portion of the moon can we see at the first quarter? at the new moon? at full moon?*

rough landing. It will be useless to release a parachute, for there is no air like ours on the moon to support it. At least there will be no danger of the rocket falling into an ocean and its occupants drowning. There are no oceans on the moon because there is no water. This is something you must realize before you look at a map of the moon. Otherwise, the names you see on the map may fool you. The astronomers who first looked at the moon through a telescope thought the large, dark areas were bodies of water. They gave the areas names such as the Sea of Showers and the Ocean of Tempests.

THE MOON'S LANDSCAPE

The mountains on the moon are unlike any on the earth. The mountains of the earth all show the effects of weathering; that is, changes produced by wind and weather. There is no weather on the moon and therefore the mountains are rough, the edges sharp. There is no soil such as ours on the moon, but there may be a thick layer of volcanic ash.

Among the first things a person landing on the moon might discover are the moon's craters. These are deep depressions in the moon's surface (Fig. 50). Two theories have been advanced. One is that the craters were formed by the eruption of giant volcanoes. Another theory is that great bodies from space crashed into the moon and tore up its surface. These craters range in size from small ones, one-tenth mile in diameter, to giants which are hundreds of miles across. They are named for famous astronomers. Some craters have high

mountains inside them. Others have smaller craters within their walls.

Besides mountains, plains, and craters, rills and rays also mark the surface of the moon. The rills are narrow, deep furrows from 10 miles to more than 300 miles long and about 2 miles wide. No one knows how deep they are. The markings called rays are mysterious. They cast no shadows. Therefore they are neither ridges nor rills. They seem to radiate from some of the craters such as those named Tycho (tī'kō), Copernicus, and Kepler. Many of the rays extend for hundreds of miles across craters, mountains, and plains.

A MAN ON THE MOON

Because the moon has no air, you could not survive on it unless you carried an air supply with you. You would need an airtight suit which would keep the air pressure on your body about the same as it is on earth.

You would weigh one-sixth as much on the moon as you do on earth. Probably you could jump over objects 20 feet high. You would also have to be prepared for temperatures ranging from 214° F. on the lighted side of the moon to −243° F. on the dark side. Could you stand these extreme changes in temperature—when you got into the shadow of a rock, for example? Because there is no atmosphere to conduct sounds, you could not hear voices or make yourself heard. You would have no water to drink, nothing to smell, nothing to eat, and no need for an umbrella. Without oxygen, you

49

The phases of the moon. These photographs are arranged to show how the moon looks at various phases throughout a single month. Full moon is shown in the center. First quarter is below it, last quarter is above it. Compare with Fig. 48. (American Museum of Natural History)

would be unable to light a fire. You would have to bring all the ordinary necessities of life with you.

ECLIPSES BY AND OF THE MOON

One of the remarkable things a visitor to the moon would experience is seeing the stars in daytime (Fig. 50). This would be possible because there is no air-borne dust on the moon as there is on the earth. The dust in the earth's atmosphere breaks up the light in a way that makes the sky appear blue. The light blue sky screens the stars from our view.

DIMOUTS AND BLACKOUTS

Oddly enough, because of the moon, there are times when even on the earth you can see the stars at noon. Few people have ever been able to see this because it happens only during a total *eclipse* of the sun. When the moon gets between us and the sun, we have an eclipse of the sun. According to one astronomer, a total eclipse of the sun occurred only twice in London and only three times in Rome in the 1200 years between 600 A.D. and 1800 A.D. In a total eclipse, the moon is directly between the earth and the sun so that the moon's shadow falls upon the earth (A in Fig. 51). The latest total eclipse of the sun observed in the United States was in 1932. The next one observable in the United States will occur in 1963. What will you see on the day of the eclipse in 1963 if you are in the area of total eclipse?

Imagine the brightness of a clear daytime sky. Then if you happen to be looking at the sun through a pair of heavily smoked glasses, you detect a dark object moving along the western edge of the sun's disk. Within a half hour, the light fades from the sky as it does when a swift thunderstorm advances. The sky darkens rapidly. Gradually the stars appear. Tiny sparks of light shine around the edge of the moon. These are known as Bailey's Beads. They are caused by the light of the sun shining through the valleys and irregularities on the surface of the moon. Then a glow much like a halo surrounds the dark disk of the moon. This halo is called the sun's *corona* (Fig. 52).

At the same time, tiny tongues of light seem to shoot out from the disk of the moon. These tongues of light really leap out from the sun. They really are tongues of flame which are always present on the sun but can be seen best during an eclipse. They extend from the sun's surface one to two million miles into space.

The moment of the total eclipse soon passes. The corona disappears. Soon the blackout of the sun becomes a dimout. In a little while, the eclipse ends. As you watch, the shadow of the moon disappears into space (Fig. 53).

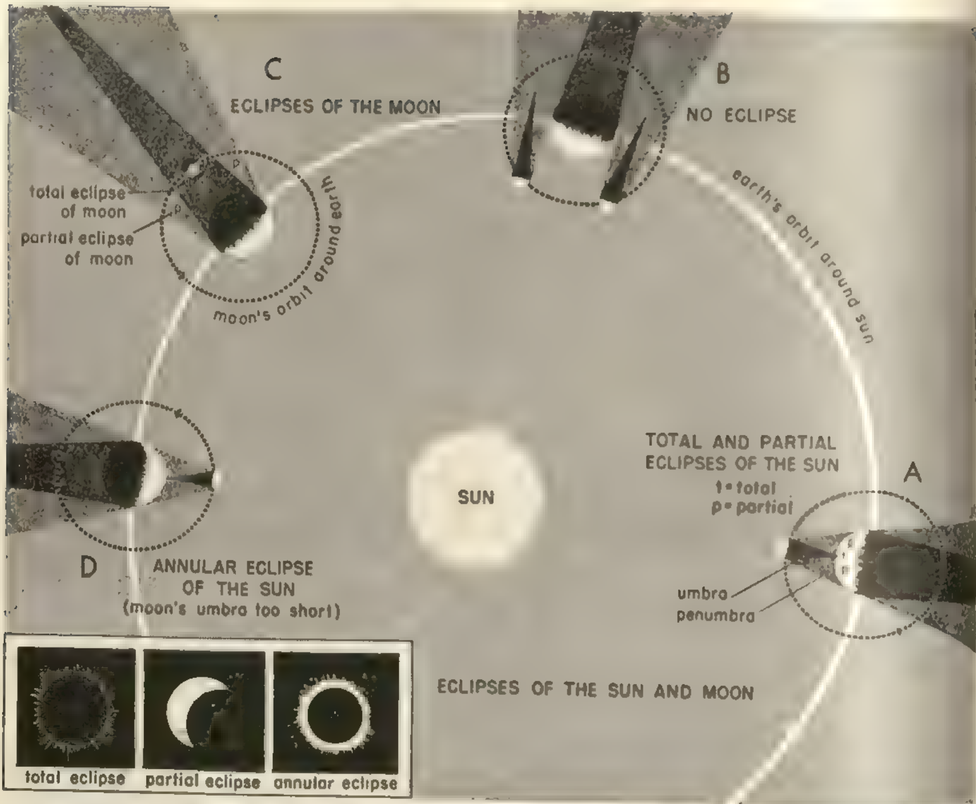
ANOTHER ECLIPSE

To see a total eclipse of the sun you have to be standing on the part of the earth touched by the dark part of the moon's shadow. This is called the *umbra* (ŭm′brȧ). Notice in Fig. 51, however, that there is a light part of the shadow as well as a dark part. Should you be standing on a portion of the earth touched by the light part of the shadow, you would not see a total eclipse. You would see only a partial eclipse. The partial eclipse occurs in the portions of the earth on either side of the dark part of the shadow, the umbra. The lighter part of the moon's

50 *The landscape of the moon as future explorers may see it. Notice the jagged, uneroded rocks, craters, curving horizon, and stars visible in the daytime.*

shadow is called the *penumbra* (pē nŭm′-brȧ).

Perhaps you haven't realized that there are light and dark shadows. It will not be necessary for you to wait for another solar eclipse to find out. Clench your fist. Hold it about four inches above a piece of white paper



51 *Study carefully this composite diagram. It shows four situations in which the positions of the earth, the sun, and the moon affect eclipses. Do you see why no eclipse would occur when the moon is in either of the positions shown in B?*

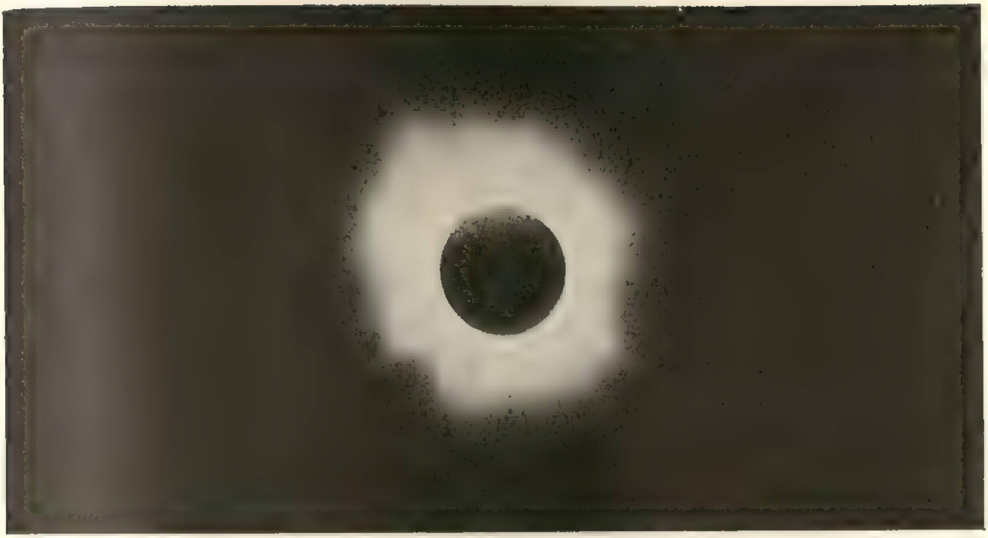
that is about two feet below a bright electric bulb. See the two shadows on the paper. The darker one, the umbra, is inside. What is the outer, light shadow called?

The earth itself also casts an umbra and a penumbra into space. At times the moon rolls into these areas (C in Fig. 51). When the moon is in the penumbra of the earth's shadow, we see a partial eclipse of the moon. When the umbra of the earth's shadow covers the moon, we see a total lunar eclipse.

You might reasonably suppose that there would be two eclipses a month. You might expect an eclipse of the sun when the new moon is between the earth and the sun. You might expect an eclipse of the moon when the earth is between the moon and the sun, at full moon (Fig. 48). There are several reasons why conditions for an eclipse of the moon or the sun are right only a few times during a year.

SHADOW TAG

Have you ever played shadow tag under a street light? Anyone who has played the game will tell you it is fun. The idea is to tag the other fellow with your shadow rather than with your hand. There is a trick to it. First, you have to be between him and the light. Second, you have to be far enough

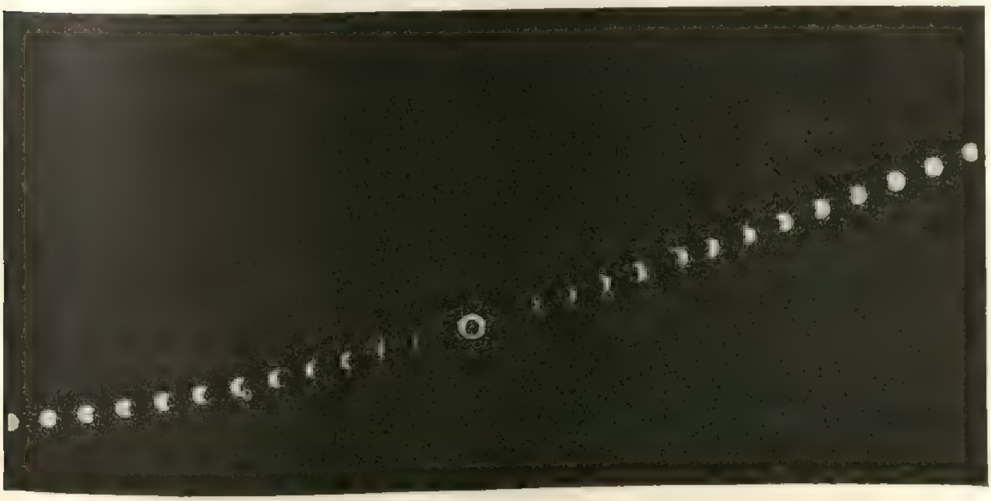


52 *The corona of the sun as it appears at the instant the sun is totally eclipsed by the moon. It is a glorious sight to see.* (*American Museum of Natural History*)

away from the light and yet near enough to the one you want to tag so that your shadow will be long enough to reach him. You see, the farther you get away from the light, the longer your shadow will be.

If you think of the earth and the moon as playing shadow tag, you will be able to understand why total eclipses occur so seldom. In the first place the earth, the moon, and the sun are nearly in a straight line only twice a month. Once, as you remember, the moon is between the earth and the sun. The other time the earth is between the moon and the sun (Fig. 48). In this

53 *Phases of a solar eclipse. There are 26 separate pictures on this photograph. Which one was made at the point of total eclipse?* (*American Museum of Natural History*)



first position there could be a solar eclipse, in the other, a lunar eclipse.

In the second place, the earth and the moon travel in orbits that are more oval than circular (Fig. 35). Sometimes they are so near to the sun that the moon's shadow is too short. Then the shadow fails to reach the earth and again no total eclipse occurs. Sometimes instead of a total eclipse we may see what is called an *annular* (ăn′ů lẽr) eclipse (D in Fig. 51). In this type of eclipse, the disk of the moon is too small to cover the sun. A ring (or *annulus* in Latin) of the sun remains around the black disk of the moon. The sky darkens no more than it would if a thick cloud were to come between us and the sun. To observe all kinds of eclipses, always protect your eyes with dark glasses such as those used by welders, or with an overexposed photograph negative.

Thinking it over, you will see how difficult it is to obtain all of the conditions necessary for eclipses of the sun and moon. When the moon is in either one of the positions shown in B of Fig. 51, there can be no eclipse of the sun. The sun, moon, and earth must be lined up and the lengths of the shadows must be right. You can see why never more than two or three eclipses of the moon occur each year and why a total eclipse of the sun seldom occurs. Eclipses of the sun are visible only to persons who happen to be in the short and narrow path of the moon's shadow. Eclipses of the moon are visible anywhere on the darkened side of the earth.

THE MOON—A BLEAK SATELLITE

Our moon is a lifeless and bleak satellite, a place of ever-changing shadows and never-changing scenery. Now you have an idea of what it would be like to visit the moon. Most of us would rather not visit it just yet. To be able to shoot a rocket at the moon and hit it—that's another story.

Experiments now being planned may produce a rocket propelled by atomic energy with enough power to overcome the gravitational attraction of the earth. To do this, the rocket must leave the earth at a speed greater than seven miles per second. Rocket builders think that they will some day be able to build a rocket capable of such speed. Who can say they will not do so? Only recently men were successful in sending radar waves to the moon and were able to record the waves on the rebound.

For the present, astronomers, both amateur and professional, content themselves with observing the moon through telescopes. Anyone who has not explored the moon through a telescope has missed an exciting adventure. Find out who has a telescope in your neighborhood and make friends with its owner. He may let you look through it at the next full moon. If no telescope is available, use a pair of binoculars to study the moon. You may see the moon's craters. You will see the dead land where perhaps sometime a rocket from the earth may land.

GOING FURTHER

1 *Examining tektites.* Tektites (tĕk′tīts) are believed to be fragments of the moon. Investigate these peculiar glassy objects. Tektites are quite rare, but some museums like the American Meteorite Museum on Highway 66 near Winslow, Arizona, have specimens on display. Meteorites striking the moon may have blasted them loose. They are not for sale.

2 *The moon's orbit.* Make a model showing the relation of the moon's orbit to the earth. Use it to explain why solar eclipses do not occur more often.

3 *Words are ideas.* Can you use these words in sentences which will give their meaning? Use the glossary.

annular eclipse	partial eclipse	total eclipse
Bailey's Beads	penumbra	umbra
corona	phases	orbit
lunar month		

4 *Put on your thinking cap.*

1. The moon is only one-quarter the diameter of the earth. How then is it possible for the moon to eclipse the sun which is more than a hundred times the diameter of the earth?

2. Why will it be difficult to send a rocket to the moon?

3. Why is the expression "an elastic shadow" a good one to use to describe the moon's shadow?

5 *Test yourself.* In your notebook, complete the following sentences with a correct word or phrase. Do not mark this book.

1. The moon is our nearest sky neighbor, being only ...... miles away from the earth.

2. The moon is only ...... miles in diameter.

3. The moon travels around the sun once every ...... and around the earth once every ....

4. Only ...... per cent of the moon's surface has ever been seen by man.

5. The moon appears to rise in the .... Each night it rises about ...... minutes later than it did on the previous night.

6. We cannot see the moon when it is exactly at the ...... phase except during an eclipse of the sun.

7. The horns of the crescent moon are always turned ...... the sun.

8. We see the moon because it reflects light from the ....

9. The temperature of the bright side of the moon is about ......° F.

10. When the moon causes a ...... we can see the sun's corona.

11. An eclipse of the moon is caused by the shadow of the ....

12. The moon can eclipse the sun only when the moon, the earth, and the sun are ....

6 *Adding to your library.*

1. *Chips from the Moon* by H. H. Nininger, Desert Press, El Centro, California, 1947. This book is about meteorites and tektites.

2. *The Story of the Moon* by Clyde Fisher, Doubleday, 1943. This is an entertaining and complete account of our lunar satellite.

3. *From the Earth to the Moon* and *Round the Moon* by Jules Verne. *The First Men in the Moon* by H. G. Wells. *The Adventures of Hans Pfalls* by Edgar Allan Poe. Read these books for amusement. You will find that although the stories are fiction, they contain a great many interesting facts. See if you can detect any scientific errors.

CHAPTER 6

OUR PLANET HOME

To learn about the earth firsthand, you have to explore it. This can be done the hard and exciting way by going to far-distant places in the Arctic or Antarctic with men like Peary and Byrd, or even under the ocean with Beebe. Or your explorations may be carried on in the safety and comfort of an armchair while you are reading a book.

If you look at Fig. 54 and read the rest of this chapter, you will make this quick safe journey. Fig. 54 shows that the earth is shaped like a ball, slightly flattened at its poles. The earth's average diameter is about 7,920 miles. This means that it is about 3,960 miles from where you are standing to the center of the earth.

You are also standing at the bottom of an ocean of air, the exact depth of which no one knows. Scientists are sure now that some air exists 500 miles or more above the earth's surface and some think it may be found 2,000 miles or more above the earth.

The oceans cover roughly 70 per cent of the surface of the earth. Their average depth is about 12,450 feet. How many miles do you suppose there are between the deepest spot in the ocean (the Emden Deep, sometimes called the Mindanao Deep, off the east coast of Mindanao, one of the Philippine Islands) and the highest mountain (Mount Everest in India)? The chart (Fig. 55) will tell you.

The world still has need for explorers. It is true that most of the surface of the earth has been seen by the eyes of men, but we know very little about the earth's heights and depths. For instance, we know very little of what goes on below its surface, in the oceans, and high up in the air.

Scientists are trying to explore both the upper atmosphere and the earth's interior. You have no doubt heard of scientists who are experimenting with rockets to learn something about the upper atmosphere (Fig. 55). Other scientists, who are trying to find out what is happening beneath the earth's surface, study earthquakes (p. 106) and learn a good bit about the earth's depths. The most recent explorations of the earth's upper atmosphere have been made with instruments in V-2 type rockets which have risen more than 100 miles into the sky. At the other extreme is Professor Otis Barton's recent 4,500-foot descent off the coast of California.

THE EARTH—AT THE BEGINNING

In Chapter 4 you studied two theories about the origin of the earth. It is now appropriate to push further and ask when this earth came into being.

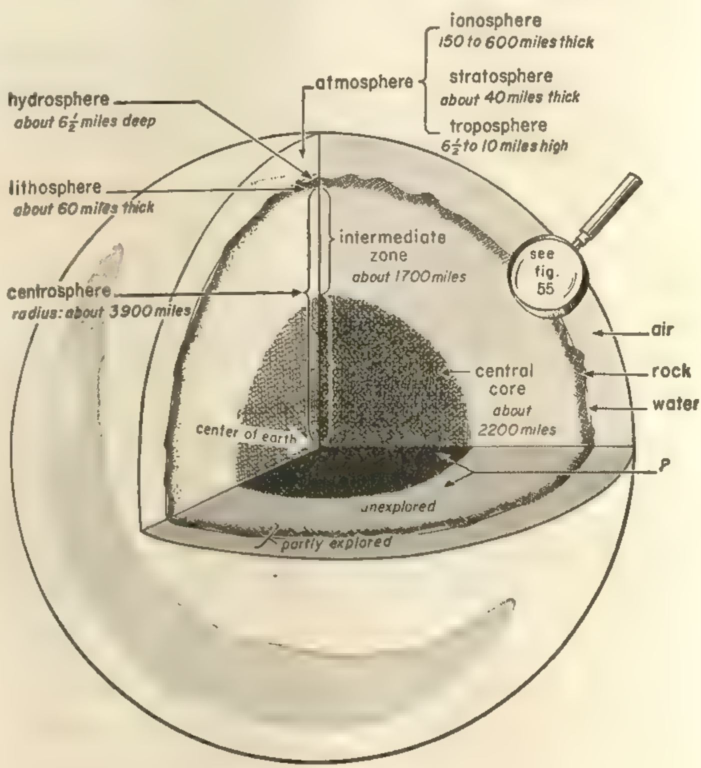
Scientists admit that their estimate may be in error because the available evidence is not complete or conclusive. Most scientists estimate that the earth is about two billion years old but some think it may be as much as five billion years old.

YEARS AGO

On what evidence do scientists base their estimates of the age of the earth? One piece of evidence comes from the fact that certain substances change very slowly into other substances. For instance, scientists know that the substance uranium can change into other substances and finally into lead. But it takes billions of years for this change into lead to occur. When the earth was formed, uranium was in its original form in the rocks of the earth. Slowly, however, it began to change. Samples of uranium-bearing rock were recently found to contain a portion of lead. By measuring the amount of lead in the sample, scientists were able to estimate how many years this lead had taken to form from the original uranium. Their estimate from this sample was about two billion years.

AT THE VERY BEGINNING

On the basis of many studies, scientists have come to two conclusions: First, no part of the earth, no mountain or rock, no continent or ocean exists now as it was in the beginning. Second, these



54
In this drawing you are looking down on a sphere representing the earth and its atmosphere. From the sphere the upper right hand portion has been cut away to show, in cross section, the inside arrangement of the earth. Here you see the four main "spheres."

changes have been going on an incredibly long time, possibly two billion years or more since the earth cooled and solidified.

How did the earth appear at the beginning? It is believed the earth began as a mass of hot gases. After the earth had cooled and solidified, it was completely barren. Later it was probably shaken by continuous earthquakes. Volcanoes must have burst out all over the earth.

Much later there were probably heavy, continuous rains as the moisture in the air condensed. The rain water collected in the broad basins which came to be our ocean beds. These rains pounded the early rocks and eventually ground them into soil. Rivers gouged out beds for themselves. We believe that there was no life at the beginning. Life developed slowly over many millions of years, but the evidence shows that man first appeared only one million or so years ago. Man developed from the living things which came before him. As you read in the first unit (p. 3), man is slowly mastering the earth. He has delved into the earth's crust and has wrested from it the minerals, food, and building materials he needs for living. The earth's crust, its oceans, and air together make up the storehouse of civilization. It is in this storehouse that man searches for what he needs for effective living.

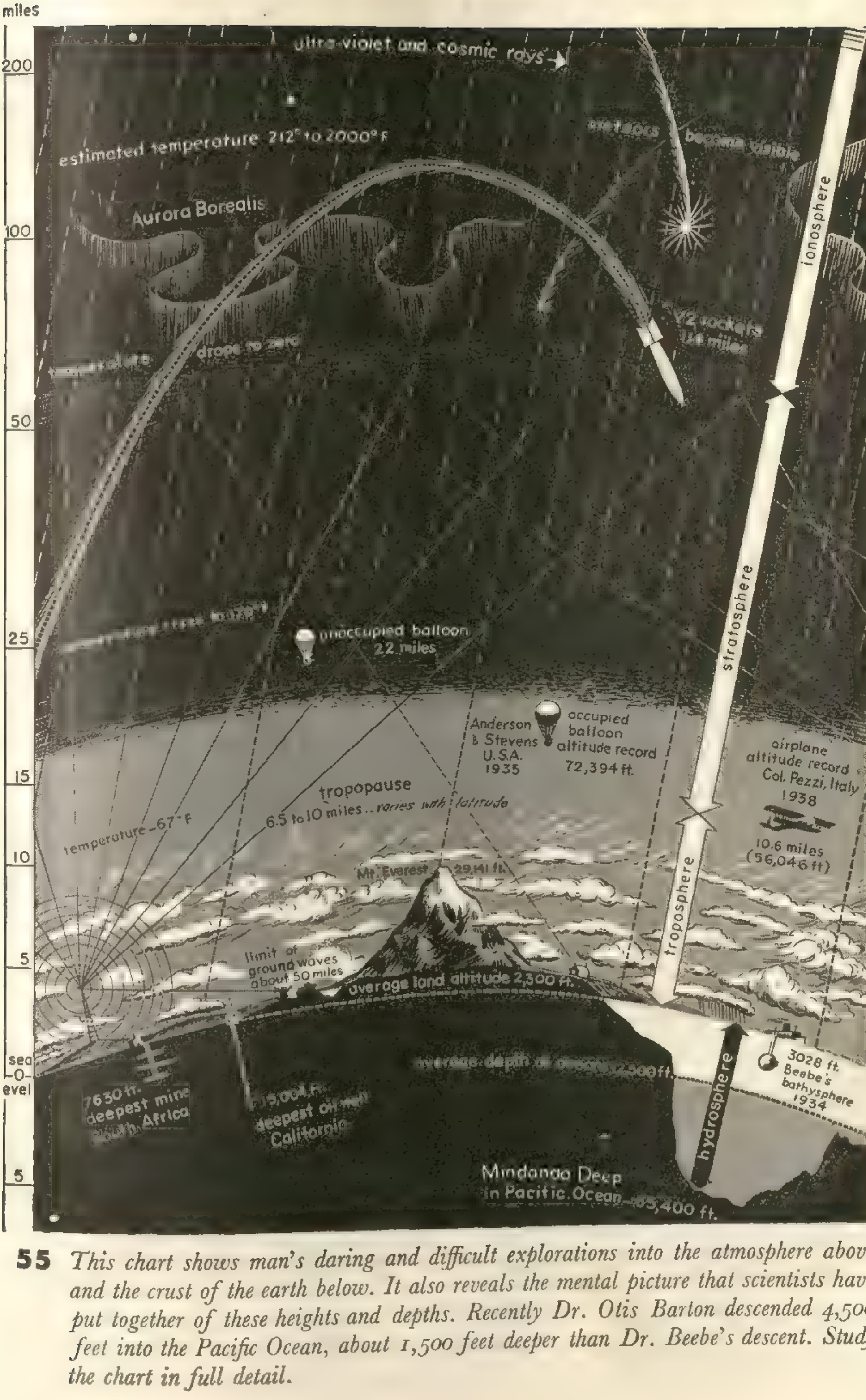
IN THE EARTH'S STOREHOUSE

Let us see what is in the storehouse. All the materials we find in it can eventually be broken down into chemical elements. For the moment, we may think of elements as the materials of which all substances in this world are made. Just as all the words in the English language may be built up from 26 letters, so all our materials are made up of 92 natural elements. Later you will learn more about certain elements, such as oxygen, sulfur, carbon, and others. You will also learn that man has recently made four new elements. Nevertheless, the original 92 elements are the basic raw materials of all the thousands upon thousands of substances we need for our health and comfort. Most of the 92 elements are found in the hard crust of the earth, which is about 40 miles thick. Table III shows the most abundant elements found in the earth's crust, the oceans, the rivers, the lakes, and the air.

However, you rarely see a chemical element when you go out for a walk. Only a few of them, such as gold, commonly exist in pure form. But combined with each other, some elements are to be found in living things: you breathe them in the air; you swim in them in ocean water; you stumble over them in the form of rocks; you step on them when you tread on soil, grass, or sidewalks.

The earth, as you can see, is made up of land, water, and air. Everyone can recognize water. It is composed of the elements hydrogen and oxygen. Air is invisible, but it is a real material having weight. It is a mixture composed of elements and combinations of elements, called compounds. Almost everywhere are different kinds of rocks; many of them are useful, and some of them are beautiful. The rocks and the materials formed from them, such as soil, are the land.

Do you have a rock collection? A good number of boys and girls do. It is one of the most interesting of hobbies. Whether you take up the hobby or not, you should know the common rocks which form the earth on which you walk.



55 *This chart shows man's daring and difficult explorations into the atmosphere above and the crust of the earth below. It also reveals the mental picture that scientists have put together of these heights and depths. Recently Dr. Otis Barton descended 4,500 feet into the Pacific Ocean, about 1,500 feet deeper than Dr. Beebe's descent. Study the chart in full detail.*

Table III. THE MOST ABUNDANT ELEMENTS IN LAND, WATER, AND AIR

The earth's crust (per cent by weight)		Oceans, rivers, lakes (per cent by weight)		The air at sea level (per cent by volume)	
oxygen	46.7	oxygen	85	nitrogen	78.
silicon	27.7	hydrogen	10.7	oxygen	21.
aluminum	8.1	chlorine	2.1	argon	.94
iron	5.0	sodium	1.2	* carbon dioxide	.03
calcium	3.7	magnesium	.14	* water vapor	varies
sodium	2.7	sulfur	.09		
potassium	2.6	calcium	.05		
magnesium	2.1	potassium	.04		
titanium	.63	bromine	.008		
hydrogen	.13	carbon	.002		
carbon	.03				

* carbon dioxide and water vapor are compounds rather than elements, but they are included here because they are such important parts of the air.

ROCKS THAT ARE FIRE-FORMED

When you pick up any rock for examination, test its hardness with a dull knife. Some rocks will crumble, others will be very hard. The hardness is an important characteristic used in identifying rocks. After testing the hardness of the rock, you should look at it to see whether it is all one color, or whether it has streaks or particles of different colors.

When your knife makes no impression on a rock, you will want to look at it closely. In some rocks, you will see tiny, shiny particles scattered throughout. Perhaps some particles will be creamy in color, and others dark. You may be able to pick out one of the shiny, glistening particles with your knife.

If you find a hard rock with these particles in it, you have probably found a piece of granite (Fig. 56). This rock is fire-formed. The term "fire-formed" is perhaps a little misleading because you yourself could not make granite by fire. But the earth made granite. When the earth began forming, it was believed to be a mass of hot gases. As the gases cooled, some of them turned into a hot liquid, called molten rock. This molten rock cooled slowly. The outer part cooled faster and formed the earth's solid crust. As the crust cooled, some of the molten rock that it enclosed burst through. This rock also cooled and became hard and solid. These rocks were once hotter than any fire you could build, and the solid masses which they formed are now called *igneous* (ĭg′nē ŭs) rocks. The word "igneous" means "fire-formed."

Granite is an igneous rock, rich in minerals. A mineral is a natural, nonliving material of uniform chemical composition. Minerals are usually associated with rocks or rock formations. Moreover, these minerals can be seen. Granite contains bits of *mica* (mī′kȧ), that flaky, transparent mineral used in the electrical systems of radios, trucks, and even battleships. You may have noticed it in stove doors or in electric toasters or fuse plugs. Granite also contains the mineral *feldspar* (fĕld′spär′). Feldspar is the name given to the creamy mineral that gives granite much of its color. Of course you have seen both mica and

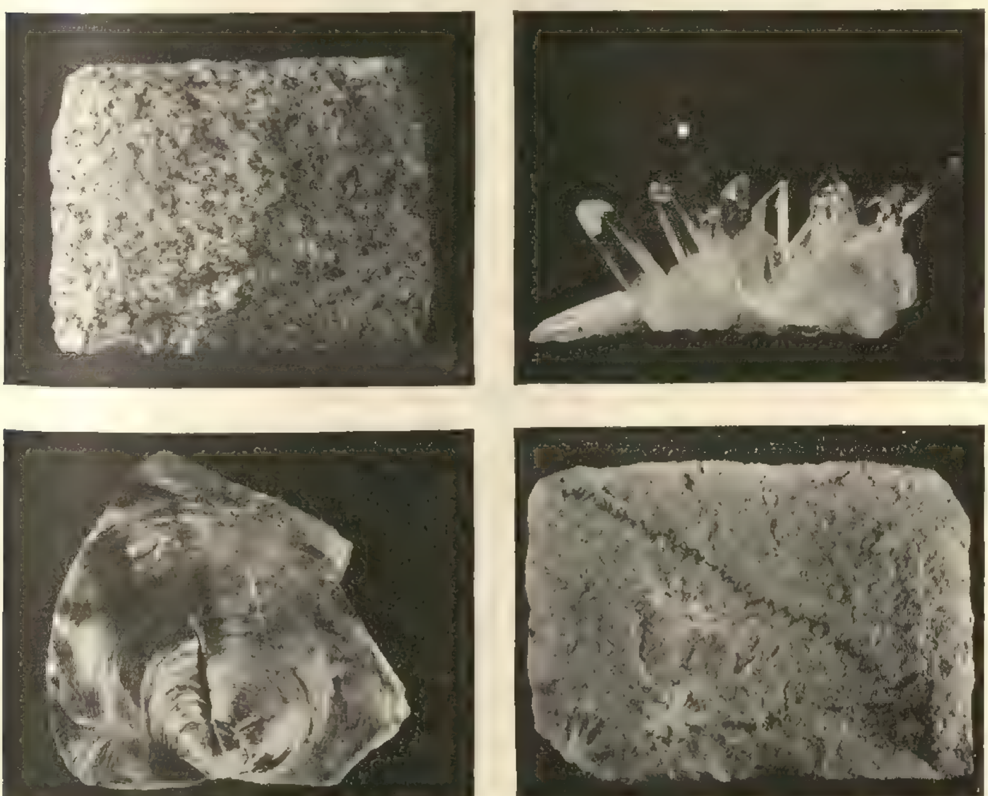
feldspar in a number of pieces of granite, but sometimes there is also a glistening mineral that looks like mica which you cannot pick out with the point of a knife because it is too hard. That substance is *quartz* (kwôrts, Fig. 56). The quartz in granite may be clear or cloudy and it shines like glass. Around it, mixed with the feldspar, is often a greenish-black substance called *hornblende;* in fact, hornblende is very common in small rocks which you might pick up anywhere.

As you know, granite is used for monuments and buildings because of its hardness.

OTHER IGNEOUS ROCK

Granite is not the only kind of rock that cooled from the depths of the earth. One hundred years ago, Indians often attacked wagon trains west of the Mississippi River. Many of the Indians were armed with spears and arrowheads made of fine-grained, black rock with sharp edges much like glass. This rock, called *obsidian* (ŏb sĭd′ĭ ăn), is produced by the cooling of molten materials thrown out by volcanoes (Fig. 56).

Would you believe that igneous rock can float on water? After an eruption of one volcano, the ocean for miles



56 *Fire-formed rocks and minerals.* (Above) *Granite and quartz crystal.* (Below) *Obsidian and basalt. By what characteristics can each be identified? (American Museum of Natural History)*

around was so thickly covered with floating stone that ships could scarcely sail through it. This stone was *pumice* (pŭm′ĭs). It is produced when gases of a volcano enter obsidian and are enclosed in it as bubbles of gas. The bubbles make the obsidian so light it will float. Pumice is sold as a scouring and polishing material because of its softness and fine grain.

Another common grained igneous rock is *basalt* (bȧ sôlt′, Fig. 56). Basalt, brown or black, is slightly coarser than obsidian and is not so glassy in appearance. Yet it is very hard and heavy and is used for building stone. You can imagine what terrific activity caused this mass of heavy molten rock to pour over the earth's surface. Many scientists think that the beds of oceans consist of basalt. Its weight would have caused it to sink into the earth's crust, thus forming the great hollows that were then filled by the oceans.

ROCKS FORMED BY WATER

It seems difficult to believe that water has formed much of the rock you see and many of the rock specimens you pick up. Yet such is the case.

If the entire North American continent should sink a distance of 700 feet, what would its appearance be? The Gulf of Mexico would reach to St. Louis, Missouri, Little Rock, Arkansas, and San Antonio, Texas. New England would be an island. Florida and the present seacoasts would be underneath the ocean, and most of Canada would be under the waters of Hudson Bay. Great inland seas would cover much of the land.

Continents have risen and sunk more than once in the long history of the earth. Continents were once partly or wholly covered by oceans for millions of years. Perhaps the ocean was once a hundred feet deep where you are now sitting. If you could have lived then at the ocean bottom, you would have seen sea animals swimming above you. As they died you would have seen their bodies settle to mix with the sand and ooze on the ocean floor at your feet. Through countless ages, the pressure of water formed these materials into layers of rocks. The pressure of an ocean is tremendous; it acts like a giant press which squeezes the particles of soil, sand, shells, and ocean ooze solidly together. Where the ocean has receded from the land, you can see these layers of rocks with the shells cemented in them.

Rock has also been formed from sediment (mud, sand, pebbles) carried into the oceans by rain, rivers, and even glaciers. There the sediment has settled and under the ocean's pressure has formed into layers of rock.

Rock that has been formed by water pressure on any sediment is called *sedimentary* rock. But how do you know that any specimen you have is this kind of rock? The following descriptions will help you recognize it.

SEDIMENTARY ROCK

Have you ever examined a piece of limestone? Limestone is a stone of such fine grain that you cannot see in it any of the individual particles from which it was made. Some of the largest quarries of limestone exist in several Midwestern states, notably Indiana. Office buildings and homes in many cities of the United States are built of limestone. In Florida there are great banks of partially formed limestone. In these banks you can see the shells of shellfish because the ocean receded before the water could finish its work. These shell banks are known as "coquina" (kō kē′nȧ). Perhaps you have traveled on Florida roads

57 *The Grand Canyon of the Colorado viewed from Grandview Point, showing layer upon layer of sedimentary rock. This is one of the most breath-taking sights in the whole country.* (*U.S. Department of Interior*)

that have been surfaced with coarse shells dug out of cemented banks of coquina.

Have you ever visited the Grand Canyon of the Colorado River (Fig. 57)? Perhaps you have seen colored pictures of its walls. Colorful bands of red and yellow seem to weave up and down the huge canyon walls. These colors come from the different kinds of sand that have been cemented by ocean pressure into a material called *sandstone.* If you live in the Middle West, you have often seen cliffs of gray, red, and white sandstone deposits. It was from red sandstone that the Indians manufactured their peace pipes.

Shale is a rock made by water pressure on mud in which there are remains of plant and sea animals. Layers of shale occur in Northeastern states and in many Western states. This shale is so fine-grained that it may split easily into long sheets. It is generally grayish black, sometimes red, and you can see the layers in which it was formed. Some shales are rich in oil that is believed to have been made by pressure on the vegetable and animal matter contained in the mud.

Where pebbles, sand, mud, and even large rocks have been pressed together, they make a mixture called *conglomerate.* Conglomerate is easily separated or broken up by the blows of a hammer or pick. You can often pick a big rock out of the mixture like a plum from a pudding. Therefore, conglomerate is sometimes called "pudding stone." Coquina (p. 100) is a conglomerate stone.

HAVE IGNEOUS AND SEDIMENTARY ROCK CHANGED?

As you have learned, there have been many changes in the earth's surface. Some of these changes brought pressure and great heat to bear on rock. Some of the igneous and sedimentary rock has changed through a remelting and cooling into what is called *metamorphic* (mĕt′ȧ môr′fĭk) rock. The word "metamorphic" means "changed."

When granite has been subjected to pressure and heat, it becomes banded. The bands are due to the separation of the feldspar, hornblende, or quartz into layers. Perhaps you have seen these different bands of colors running across the face of a granite cliff. These bands may be straight, crumpled, or wavy. Even small specimens have banded structures. Such banded rock is known as *gneiss* (nīs). Gneiss exists mainly where pressure has forced rock upward through the earth's surface.

Slate is the result of action of heat and pressure on shale. Because it has layers like the shale from which it is made, slate cleaves or splits easily. Thus it can be shaped for roofing and for school blackboards.

Limestone also changes under great heat and pressure. Instead of becoming finer-grained, the limestone becomes coarser, with large crystals of different materials in streaks or bands scattered through it. This changed, harder limestone is called *marble*. Marble has always been regarded as one of the most beautiful and decorative rocks of the earth.

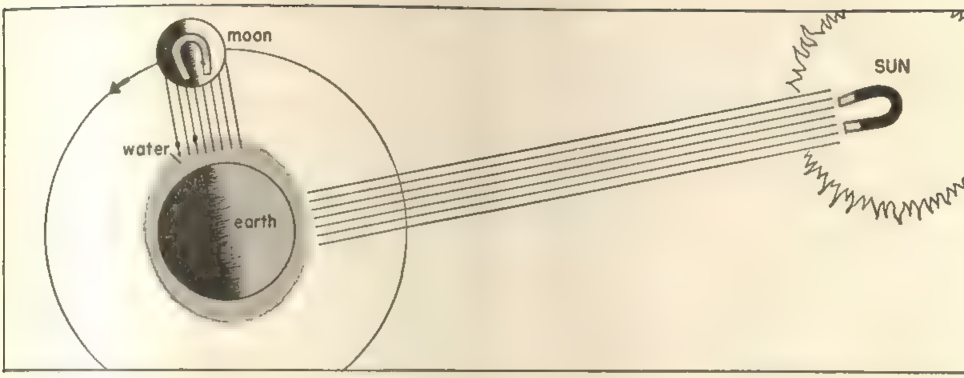
A FORCE WHICH RULES OUR EARTH

As you look at a globe representing the earth, you may wonder what keeps the rocks, the air, and the oceans in place. Why don't the loose rocks fall out into space? Why don't the oceans spill out into space? Why don't you yourself fall out into space? Perhaps you think these questions are silly. If you were standing at the North Pole and another person at the South Pole wouldn't one of you fall off? Only one of you would be standing "on top." Well, part of the answer is that there is no top or bottom to this earth. Every one of us, everything, every ocean and rock is held to this earth by a force called *gravity*. Let's test this force.

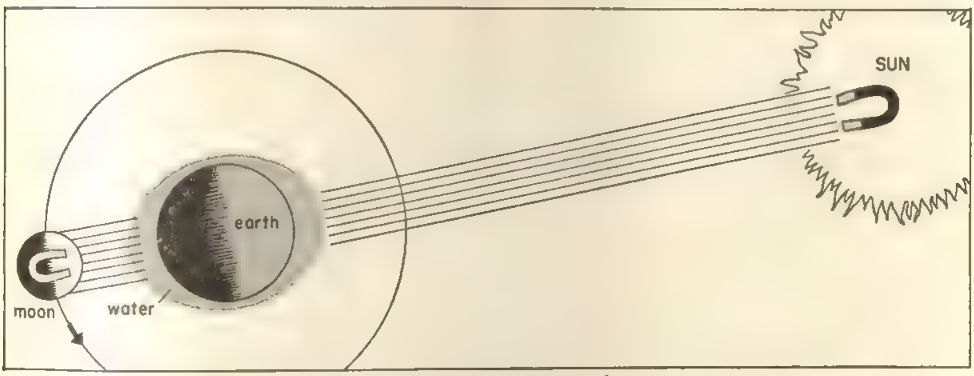
GRAVITY

How much do you weigh? Did you know that at the North Pole you would weigh more than at the equator? In the previous chapter on the moon, you learned that you would weigh one-sixth as much on the moon as you weigh on the earth. Why?

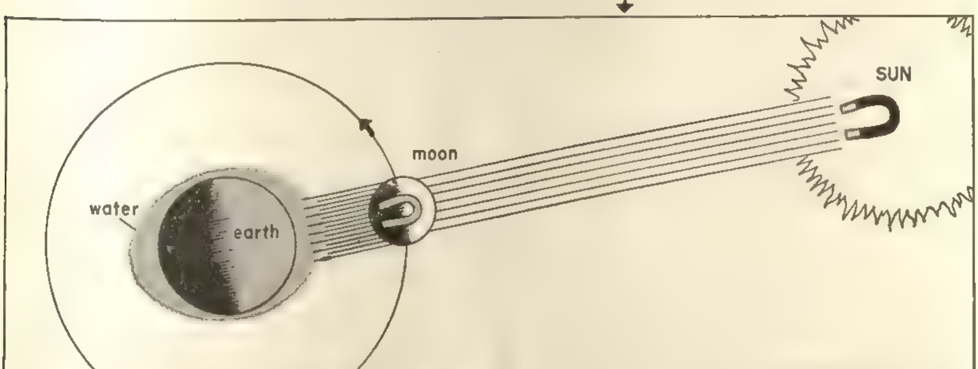
About three centuries ago, Sir Isaac Newton first explained in scientific language the reason why things differ in weight. It is due in part to gravity. Newton described the force of gravity in his Law of Universal Gravitation. This law states that every object in the universe attracts every other object. For example, the earth and you have a great attraction for each other. When you weigh yourself, you are measuring the amount of this attraction between yourself and the earth. Your total weight is the total force with which the earth pulls on you. Where is this force situated? Scientists say the earth attracts objects—you, the moon, air—as if its force of attraction were concentrated at the center of the earth. The farther you are from the center of the earth, the less is your weight. The earth is somewhat flatter at the poles. Therefore, a person at either the North



moderately high and low tides



highest high and lowest low tides



58 *The highest high tides occur on opposite sides of the earth when the sun, the earth, and the moon are in a straight line. When the sun and moon are out of line the tides are more moderate. What do the magnets drawn in the sun and moon represent?*

or South Pole is nearer the center of the earth than a person at the equator. Consequently the person at the North or South Pole weighs more.

Scientists have also found that the smaller the mass of an object, the less is its gravity pull. The gravity pull of the moon is one-sixth that of the earth. You would weigh, therefore, one-sixth of your present weight (earth weight) on the

moon. Perhaps man may sometime be able to test this statement. In any event, if you were on the moon, you would wear heavy shoes to make up for your loss in weight. Otherwise, every step you would take would be a jump carrying you six times as far as an ordinary step on the earth.

The force of gravity greatly affects the lives of the people living on the earth. This force keeps the air and every object on the earth from being projected out into space.

The sun, having a mass more than a million times that of the earth, exerts a tremendous gravity pull which holds the earth in its orbit. The other planets also are held in their orbits by the sun and they in turn hold their moons as satellites.

You may wonder why the force of gravity does not pull all of the planets right into the sun, the center of our solar system. You know this does not happen. The reason is that the earth is moving rapidly in space and tends to move in a straight line like any other rapidly moving object. The result is that the inward pull toward the sun and the outward movement of the earth counteract each other and keep the earth in its orbit.

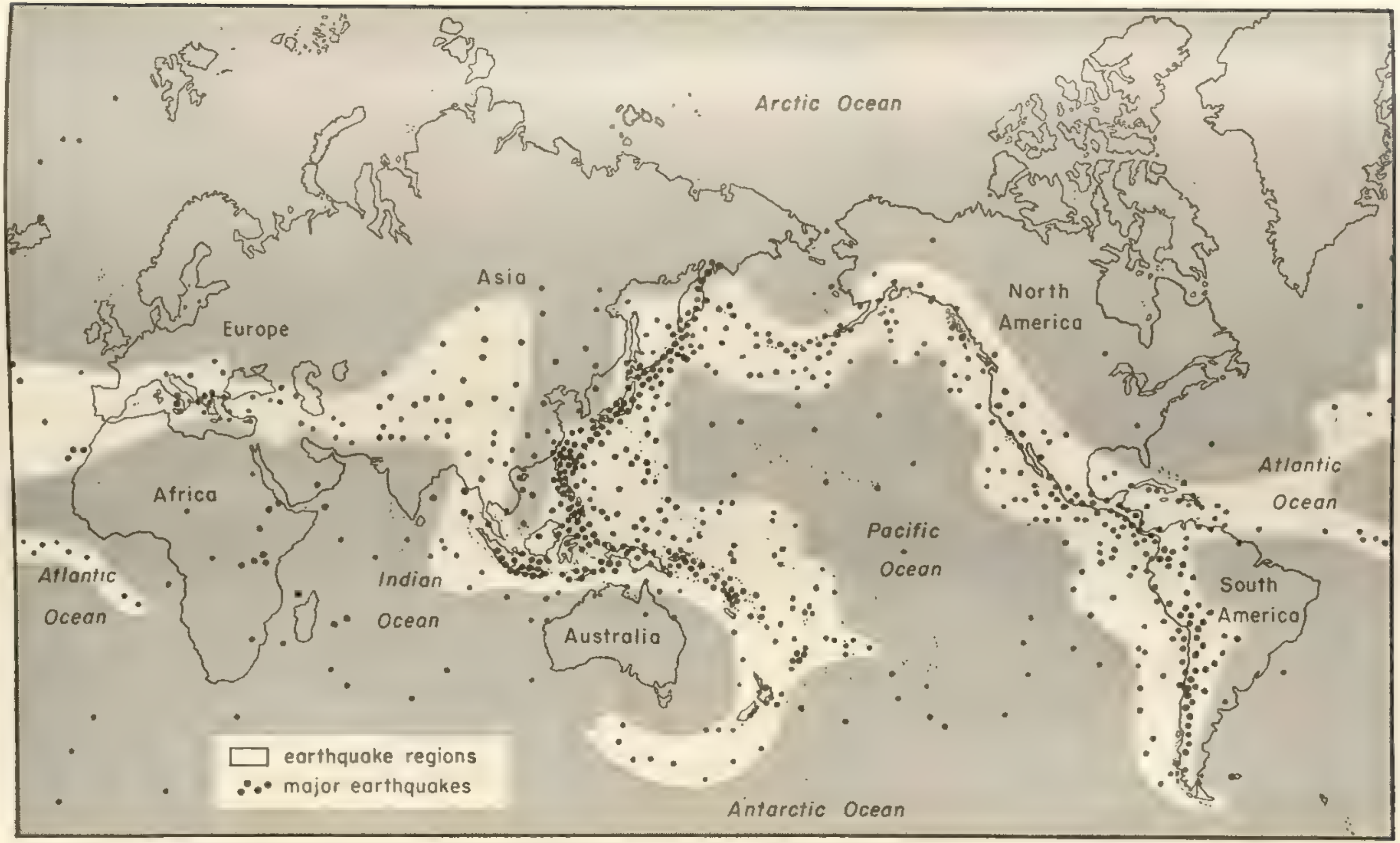
THE TIDES

You know now that both the sun and the moon exert a pull on the earth. But you may be surprised to learn that the moon has a greater effect on the tides than the sun has. This is so because the moon (although it is so much smaller than the sun) is so much nearer to the earth. The sun being farther away (93,000,000 miles or 370 times as far away as the moon) exerts a smaller pull in spite of its greater mass. For the pull of gravity depends not only upon the mass of the objects but also upon the distance between them. The moon, being about 370 times nearer to the earth than the sun, exerts a much greater influence upon the earth than does the sun.

The pull of the sun and moon on the earth produces little noticeable effect on the land. However, the water of the oceans can move freely, and the pull of the sun and moon causes a regular movement in them. This movement of water is called the tides. If you have ever visited the seashore, you know that the water rises along the shore for a period of six hours and falls away for another six hours twice a day. When the tide is out on our Atlantic seacoast, it is also out along some other coast halfway around the world. One quarter of the way around the world in either direction you would find high tides at the same moment. The diagram in Fig. 58 will make this clear.

Tides are important to men who go down to the sea in ships. Large ocean liners can enter and leave certain harbors only at high tide. Shell fishermen work along the shore harvesting clams and oysters when the tide is low. Tides also help to keep our harbors clean but they often litter our bathing beaches with debris from ships, broken piers, and garbage thrown overboard far out at sea. The greatest difference in water level occurs at spring tide, the least at neap tide. These special tides are produced by the sun and the changing positions of the moon and the sun.

When new or full, the moon is most nearly in line with the earth and the sun. By studying Fig. 58, can you see why the highest and lowest tides are produced when the sun, the earth, and the moon are in line? The gravitational forces of both the sun and the moon are working together to produce these tides.



59 *"The Earthquake Belt" of the world. Where do the most earthquakes occur? How do you account for this?*

When the moon is at the first or third quarter position, the opposite is true. Now, the moon is producing a moderately high tide despite the pull of the sun in another direction. You can see why these tides are not as high or as low as those which occur when the moon and sun are pulling together. Study Fig. 58 to get a clear picture of tides.

Thus you see how important an influence the force of gravity is when it is exerted by objects the size of the sun or the moon. You may easily discover many more examples of the great importance of this force. For example, have you seen the three rings of Saturn (Fig. 36)? These are composed of thousands of small moonlike bodies. What keeps them circling in a ring about Saturn? Why don't they fly off into space?

OUR EARTH IS STILL NOT STABLE

You may think that since the earth is some two billion years old it should be pretty stable or set in its ways. This is not so. In this book, we cannot deal with all the changes that take place in the earth. You will learn about them as you study more science. But there are several types of changes that affect your daily lives. Some of these you will learn about here. As you read, you will understand why you should know something about earthquakes, volcanic eruptions, and erosion.

EARTHQUAKES

Look at the map in Fig. 59. It shows you what is often called "The Earthquake Belt." It might also be called "The Volcano Belt." Most of the active volcanoes and most of the serious earthquakes occur within the shaded areas on this map.

Between the years 1899 and 1923, 1,783 major earthquakes occurred in the shaded areas on the map. One area you can see nearly encircles the middle of the earth and the other nearly encircles the Pacific Ocean. Remember that these 1,783 earthquakes were major quakes. A major earthquake is one that has been recorded on instruments in widely separated parts of the earth. Another 100,000 lesser quakes probably occurred during the same years.

THE CAUSES OF EARTHQUAKES

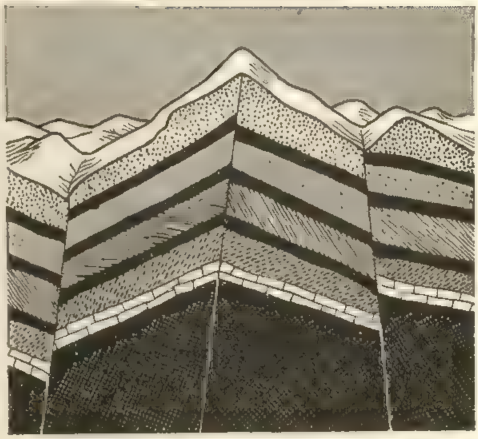
The instruments used to record earthquakes are known as *seismographs* (sīz′mô grăfs). By studying the seismographic records of many earthquakes, scientists have discovered what causes them. Have you ever tried to lift a rock or boulder the size of a basketball? Rather heavy, wasn't it? Now try to imagine the tremendous weight of a pile of rocks a mile high, five miles high, fifty miles high! Down inside the earth at depths of five to fifty miles the total weight of the rocks exerts tremendous pressure.

This pressure causes cracks or *faults* which may extend for several miles into the depths of these rock masses (Fig. 60). Suddenly a mass of rocks gives way to the pressure and slips a short distance downward or sideways along one of the faults. This movement sets up vibrations called *shock waves*. These waves travel outward in all directions like the ripples on a pond when you toss in a stone. But unlike ripples on water, these waves travel in all directions, upwards, downwards, and sideways.

These shock waves are not water waves; they are land waves. They are

no mere ripples. To give you an idea of their size consider the earthquake that struck the Shensi (shĕn'sē') Province of China in January 1556. Entire villages, disappearing like toy houses in a box of sand, were buried by the loose, moving soil. The Chinese said that the mountains seemed to walk. This disaster took the lives of several hundred thousand people. In the summer of 1949 an earthquake in Ecuador destroyed several villages and took the lives of some 4,000 people.

Usually, the greatest destruction is caused in the region right above the spot where the rockslide has taken place within the earth. If the earthquake occurs beneath the ocean, it sets the water in motion and creates a huge ocean wave, often called a tidal wave. Sometimes seacoast villages hundreds or thousands of miles away may be destroyed when the great wave sweeps over them hours later. Such a wave struck Hawaii in the winter of 1948.



60 *Faults in rock formations. Notice how the cracks extend deep down through many layers of the rock crust. How would an examination of the rocks on both sides of a fault reveal that a movement of the rocks had occurred?*

VOLCANOES ARE SAFETY VALVES

If a volcano began to erupt in your backyard or pasture, you would probably not regard it as a symbol of safety. Nor would those of you who have read of the destruction and death caused by the eruption of Vesuvius, Etna, Stromboli, Krakatoa, or Mount Pelée. Nevertheless, a volcano on the earth is like a safety valve on a steam boiler. Once in a while when the steam pressure gets too high the valve blows off. A volcano is a crater or hole leading down like a chimney into the earth at a spot where the rock crust is very weak. In the volcano, molten rock and steam penetrate through the thin crust.

Most of the active volcanoes lie within the great earthquake belts. Because of this some people jump to the conclusion that volcanoes are the common cause of all earthquakes. It is true that volcanoes sometimes cause minor earthquakes in their immediate vicinity. Remember, however, that rockslides deep down in the earth cause most of the major quakes. But volcanic eruptions and all that goes with them are exceedingly dangerous to living things near the area of the eruption. When a volcano erupts there may be local quakes, flying boulders, syrupy streams of flaming lava, fiery cinders raining down, and death-dealing clouds of hot, poisonous gas.

Having read all this, you may be surprised to know that in spite of the destruction they cause, earthquakes and volcanoes are considered by many scientists to be constructive and valuable to man. All we can say here is that where they occur you will find the highest mountains and the richest mineral resources. When rocks shift and the earth cracks, when volcanoes erupt,

new materials are brought to the surface. Here the earth is being rebuilt.

However, rebuilding does not always appear where destruction of the earth occurs. All around you, every minute of the day, a mild but costly kind of destruction of the earth goes on.

WEARING DOWN THE EARTH

The men who paint big bridges like the George Washington Bridge in New York City or the Golden Gate Bridge in San Francisco are never finished. If they do not paint these bridges regularly, the bridges will be destroyed by the action of the weather. Examine the surfaces of the exposed rocks in the northern parts of our country and Canada. They show the huge scratches of a great mass of ice, called a glacier, that bore down some 25,000 to 30,000 years ago, grinding the rocks and moving away the soil in its path.

Every hillside shows the effects of the rain. Look at any slope that has not been repaired after a storm and notice the changes. See how the rocks have peeled off the front of any cliff. Look at the pictures of rocks carved by the wind and by the waves.

Weathering is constantly changing the face of the earth. In weathering, sun, wind, water, ice, and rain act on the earth and buildings and wear them away. The wind carries sand which rasps away at rocks. The ocean waves beat upon the shore and break up its rocks and soil. Cliffs may be worn away and topple into the ocean. Water seeps between the cracks of rocks. In winter, this water becomes ice. As you know, when water becomes ice it expands. As it expands, it cracks the rock and breaks it down. Water also speeds the rusting of steel and iron. Unpainted steel structures, weakened by rusting, collapse.

Erosion is a word which is also used to describe wearing away. Generally, erosion is used to describe the wearing away of land by water and wind. Creeks and rivers carry away the soil of the land through which they flow. Rains beat upon land unprotected by growing trees, shrubs, or grass and carry the soil away. Wind picks up unprotected soil and carries it in dust storms to other places. The dust storms in certain states in our West ruin many a farm (Fig. 61). The Mississippi River steals 730,000,000 tons of soil yearly and deposits most of it in the Gulf of Mexico.

Weathering and erosion are the great destroyers of our soil. Man has been able to protect his farm land to only a slight extent against the action of the winds and the flow of water.

Throughout the ages in which this earth has existed weathering and erosion have been going on steadily. The Appalachian Mountains were once tall, peaked, and rugged like the Rockies. Now they are gentle, comparatively low, rolling mountains. In millions of years, the Rocky Mountains will become like the Appalachians. The Mississippi River was once a fast-flowing, turbulent, roaring stream like the upper reaches of the Missouri River. Now at certain places it is slow-flowing and shallow. As the upper Missouri River cuts away at its canyons, it, too, will fill with soil and rocks. Eventually they will make its river bed shallow as the river becomes relatively gentle.

Next time you go out into the woods or go fishing, look for the effects of erosion and weathering. But you may have guessed that while the land is being worn away in one place, it must be built up elsewhere. For, as you remember, every soil particle and every rock is chained by gravity to this earth.

BUILDING UP THE LAND

When soil is carried away by a river, it is deposited near the river's mouth. This deposit of fine soil spreads out in a fan-shaped area called a *delta* (Fig. 62). The delta of the Mississippi is in the Gulf of Mexico and is made of fine fertile soil. The delta of the Nile River in Egypt extends out into the sea 200 miles. The Rhine River of Germany and Holland has built a fertile delta on which fine crops grow. In short, while rivers carry away soil and sediment from one part of the land, they deposit it in another part. They deposit soil either on their banks, in deltas, or out in the ocean.

As land is worn down in one place, it is built up in another. Thus, rains wash the soil of hills and mountains into the valleys. Rivers wear away the sides of canyons and bring the rock and soil to the lower reaches of the river, or to deltas. Glaciers grind against rock and carry the broken rock to another place. Cliffs which are eroded by ocean waves become part of the ocean bed.

UPLIFTING LAND

Weathering and erosion do their work slowly. Eventually, soil and rock are shifted from mountains to valleys, from fertile hills to deltas. Tremendous amounts of soil and rock in billions upon billions of tons are transferred from one part of the earth to another.

Over millions of years the areas where soil and rock are deposited become much heavier than the areas from which they are removed. The result, according to some geologists, is that tremendous pressure on the earth is found in the areas where soil has been deposited. Eventually this pressure pushes up the land in the areas from which soil is removed.

You will get an idea of how this happens if you squeeze some bread dough with your fingers. Your finger

61 *The life-giving soil of this Southwestern farm has been destroyed by wind erosion. How can you tell that the soil is of little value?* (Soil Conservation Service)

pressure is to be compared to the pressure of billions upon billions of tons of soil. Notice that as you press down on one part of the dough, another part pushes up. Of course, the earth is not dough, but the idea is that pressure in one place causes uplifting of land in another. And there is ample proof, too lengthy to be given here, to show that this uplifting takes millions of years.

Volcanoes and earthquakes are destructive but they may also build up land. During the eruption of a volcano, large amounts of rock and lava are hurled into the air. They fall around the volcano and may build it up into a mountain. Mount Rainier in Washington and Larsen Peak in California were originally volcanoes.

In certain kinds of earthquakes, the earth faults. When this happens, part of the earth heaves up and may form a flat or block mountain (Fig. 63). In southern Oregon there are many such block mountains. The block mountains of Nevada and Utah are much older than those in Oregon.

Thus the surface of our earth has been torn down and built up. Every time you see erosion going on, the earth is being torn down. But as this happens, other areas are being built up. Ocean floors are forever increasing in weight. Then over millions of years the pressure in these built-up areas may cause an uplifting of mountains in the areas which have been torn down. So the earth is not stable at all. Over the millions of years it keeps changing, wearing away in some places but building up in others.

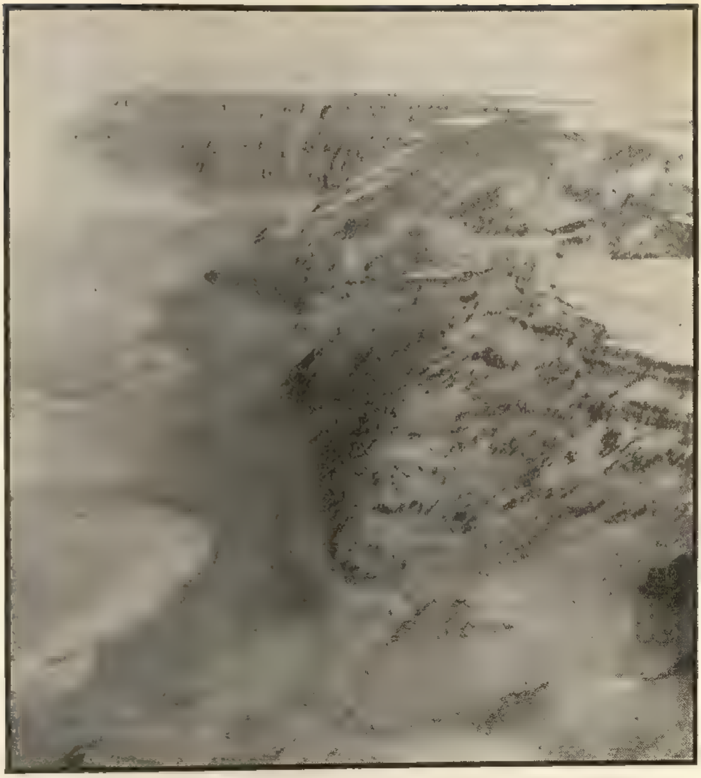
At present all our resources are to be found on this earth. We must use our supplies of oil, coal, metals, water, and our soil wisely. Man is ingenious, man is resourceful, man is an inventor, but this earth still remains, at present, his storehouse of civilization. He must learn to use his storehouse well.

GOING FURTHER

1 *Making a rock collection.* Make a collection of rocks and sort them into three kinds: igneous, sedimentary, and metamorphic.

2 *Experimenting with mica.* Find a piece of mica. Pull off one layer and then another. See how thin a layer you can separate. Put a piece of mica over the center ter-

62
Delta at the mouth of the Mississippi River. Where did the soil that forms the delta come from? (U.S. War Department)



63
Steens Mountain, a block mountain in southeast Oregon. How could an examination of the rocks of this mountain reveal that it had been lifted above the surrounding plain? (*Photo by R. E. Fuller from Physical Geology by C. R. Longwell*)

minal of a flashlight battery. Now flash the light. What do you conclude about the ability of mica to conduct electricity? Try other things, such as a piece of paper, a piece of asbestos, a piece of tin, in place of the mica. Draw conclusions.

3 *Testing for marble.* Take pea-sized pieces of marble, granite, and other rocks. Place each piece in a test tube or a glass tumbler. Add some vinegar to each. You will find that bubbles of gas start to form in one test tube. This gas is carbon dioxide. Marble gives off carbon dioxide because it is made up of a substance called calcium carbonate. How would you determine whether a rock is marble?

4 *Words are ideas.* Can you use these words in a sentence which will give their meaning? Use the glossary.

lava	sandstone	seismograph
mica	sedimentary	fault
limestone	igneous	earthquake
granite	metamorphic	delta
slate	mineral	weathering
shale	volcano	erosion

5 *Put on your thinking cap.*

1. Why are the forces of erosion responsible for greater destruction than earthquakes and volcanoes?

2. Support or refute the statement, "Nothing is changeless except change." Use the earth as an example.

3. If erosion and lack of care for our natural resources continue, what do you think our world will be like a hundred years from now?

6 *Test yourself.* In your notebook, complete the following sentences with a correct word or phrase. Do not mark this book.

1. You are standing at the bottom of an ocean of ....

2. Theories about the age of the earth are based in part on a study of the changes in the substance ....

3. In the beginning, the earth was a mass of

4. The number of naturally occurring elements is ......

...... elements have been made by man.

5. Of all elements ...... occurs in largest quantity; ...... is next.

6. The rocks of the earth that were originally formed by fire are known as ...... rocks.

7. The rocks that were deposited under water are called ...... rocks.

8. The rocks that show they have been changed from their original composition are called ...... rocks.

9. Many common rocks contain valuable ......

10. ...... show that the interior of the earth is still very hot. Earthquakes usually occur where there are ...... in the earth. To locate an earthquake from a distant point, scientists use an instrument called a ......

11. One of the major forces causing changes in the earth is gravity, the laws of which were first stated by ...... This force accounts for the ...... on the earth which are caused by the pull of the sun and the ......

7 *Adding to your library.*

1. "Last Days of St. Pierre" by Fairfax Downey in *People in Literature* or *Disaster Fighters*. This is a vivid account of the violent and sudden death that follows in the wake of a volcanic eruption.

2. *The Earth* by Chester A. Reeds, University Society, New York, is a very thorough account of the earth's evolution.

3. *Earthquakes* by Chester A. Reeds, American Museum of Natural History Guide Leaflet No. 85. This is fascinating reading.

4. *Rocks and Minerals*, Merit Badge Series, Boy Scouts of America, Catalogue No. 3357. This is a must for young rock collectors.

8 *Men and women wanted.* Do you want to be a geologist? Perhaps you would like to know more about what they do. Geologists study the earth, its rocks, its metals, and its minerals. Industries employ geologists to locate minerals for them in all parts of the world. In a very real sense geologists are world explorers. You can start by collecting minerals. It is an excellent hobby and it may grow into a lifework.

CHAPTER 7

OUR LIVING NEIGHBORS

If you were to take a walk in the Peruvian city of Oroya, you would have to walk much more slowly than you normally do in your home town or city. Even at this slow pace you would be panting with exertion and sweat would roll down your forehead before you had walked two blocks. You might not be able to live in Oroya at all. Most people who visit this city cannot stay there even for a day. They are taken with mountain sickness; they become dizzy, short of breath, and cannot retain food. Oroya is approximately three and a half miles (17,000 feet) above sea level, in the Andes Mountains.

At 10,000 feet above sea level (about two miles) United States army aviators are required to put on their oxygen masks. Yet here in Oroya about one mile above the point where army aviators must use oxygen, men of the Andes live well; they are active and healthy. Scientists who have spent many years studying this Andean man find that he is, on the average, a stocky, well-built fellow. His heart can do 12 per cent more work than ours does. His lungs are larger and can take in one-third more air than ours can. His blood has more of the cells which carry oxygen than ours has. His blood can carry more oxygen to his tissues. Peruvian aviators from the Andes are able to fly 10,000 feet higher than our own aviators without taking oxygen. In other words, because of his ability to take in more air and because his blood is fitted to carry more oxygen, Andean man is fitted for life in his city of the skies. Scientists say that Andean man is adapted to his environment. Because he is adapted, he lives in an environment where most men find it impossible to survive. And as you read this chapter, you will learn that all plants and animals which are not adapted to their environment cannot survive. They die.

BEING ADAPTED

Adaptation means being suited to live and reproduce in a certain environment. For instance, the body and fins of a fish enable it to swim in water. Its gills enable it to get oxygen from water. A fish is not adapted to living on land; it dies in such an environment.

64 *Snow geese at the National Wildlife Refuge in California. How are birds adapted for air travel?* (*U.S. Fish and Wildlife Service*)

A rabbit is adapted for breathing air. So are you. Your lungs are not adapted to breathing oxygen from water.

Birds are adapted to flying. Their hollow bones give them light bodies; their wings, their tails, as well as their streamlined bodies fit them for movement in air (Fig. 64). Their oiled feathers protect their bodies against rain or the water in which some birds swim.

Thus all living things are adapted to the type of environment in which they live and reproduce. Desert plants, like the cactus, can live on small amounts of water. Many of them store it for use in times of drought (Fig. 65). However, you will find no beech trees or geraniums in a desert. They are not adapted to a desert environment. What happens when the environment changes and the living things in it are not adapted to the new conditions of their environment?

THE PRICE OF NOT BEING ADAPTED

No doubt you have visited a museum and seen the bones of ancient reptiles, such as dinosaurs (dī′nô sôrz, Fig. 3). You may have seen the huge king dinosaur, 18 feet high, its enormous head filled with pointed teeth, each the size of your fist. You may have seen the thunder reptile, some 40 tons in weight. These creatures do not exist today.

Why did they die out? One theory is that the land in which they lived changed from a wet, lush, swampy one to a land that was fairly dry and prairie-like. In spite of their huge size and fierce looks, many of these reptiles lived on plants. When the plants they used as food began to disappear, they disappeared too. The dinosaurs were not fitted to the new environment.

How would you judge whether a plant or animal is well adapted to its environ-

ment? By the fact that it lives? Scientists use at least two standards to test adaptation. They ask: Does the living thing reproduce its own numbers? How widely is it distributed? Let us apply these standards to several test cases.

THE EMPEROR PENGUIN

The scientists with Admiral Byrd's expedition to the Antarctic carefully studied the emperor penguin. They noticed it could not fly. They observed how its young hatched in the subzero weather. They noticed how tough the bird was, how it resisted injury. They saw how adept it was at getting its food —fish, shrimp, shellfish. It had no enemies to speak of and its numbers remained constant. It is well adapted to the cold of the Antarctic. It does not move very far because it needs a special environment in which to live.

MAN

Because he has a remarkable brain, man is especially good at mastering various types of environment. His airplanes enable him to compete with the birds; his submarines and ships with the fish; his automobiles with the horse. His clothing and his heating devices enable him to master cold climates; his refrigeration systems enable him to master hot climates. He is increasing his numbers. He has spread over the earth. He is, therefore, well adapted to the present environment, and his environment has broadened to take in nearly the whole earth. This entire book is really the story of man's ability to master his environment.

Thus, you see, applying the standards of adaptation, both the emperor penguin and man reproduce their numbers. The emperor penguin is adapted to a special environment while man can master most environmental conditions. Man is, therefore, a more successful animal. Man need not fear penguins because they cannot compete with him. Man need fear only those animals who can outnumber him and compete with him in his own environment. Has he such competition?

MAN'S CHIEF COMPETITORS

Scientists who study insects and their habits are constantly reminding us that if we should stop our fight against insects for one season, we should soon lose our dominant position on earth. They point out that there are almost 600,000 different kinds of insects. They inhabit all parts of the world. They greatly outnumber man. In Chapter 20, you will read how man's fight against insects goes on unceasingly. Right now

65 *A cactus. With few branches, no leaves, and space for storing water, it is well adapted to survive in dry country. (American Museum of Natural History)*

we are holding our own. However, there are still certain places in Africa in which disease-carrying insects make whole areas uninhabitable for man.

Another of man's competitors is a group of animals called rodents (rō′-dĕnts). In this group, we find rats, mice, rabbits, prairie dogs, lemmings, beavers, and other similar gnawing animals. They reproduce in large numbers, feeding on grains and other plants.

As measured by our standards of adaptation, the insects and the rodents are well adapted. They are so well adapted to the environment of this earth that they compete with man wherever he is. And man has to keep them in check wherever he is or they will destroy his food supply (Chap. 20) or kill him with the diseases they carry (Chap. 32). It is clear, then, that those animals and plants which are maintaining or increasing their numbers are adapted to their environment.

66 *A heron. How did destruction of these birds upset the balance in a Florida lake? (American Museum of Natural History)*

BALANCE

There are on this earth approximately one million different kinds of animals and one-third as many different kinds of plants. How do these plants and animals live together? Why is it that the biggest or the most powerful or the fastest multiplying plants or animals do not eliminate the others and thus cover the earth with their own kind? Do you think this is possible? Here is some evidence which will help you decide.

MISTAKE NO. 1

In a Southern fishing town, the fishermen got together at town meeting and voted a bounty for every heron brought in (Fig. 66). The herons, they said, were destroying their fishing grounds. They had watched these birds feed on fish. Since there were thousands of herons, there must have been quite a large loss of fish and quite a large loss in profits.

The bounty plan worked. Herons were brought in by the dozens. Soon there were very few herons about. For a good number of years the fishermen enjoyed heavy catches. But after many years, their catches began to get smaller again. Soon a number of fishermen were out of business because there were very few fish. At this point scientists were called in for advice and here is what they found.

When the herons were killed, the fish began to multiply. They fed on water plants. However, the water plants could not keep on reproducing in numbers sufficient to feed the fish. For the plants, surprisingly enough, depended on the herons. The herons' droppings furnished the plants with some of the chemicals they needed to make food. So while the herons ate some fish, they really were responsible

67 *Buffalo grazing. Are these animals herbivores or carnivores?* (*U.S. Forest Service*)

in part for keeping the number of fish high. The droppings from the herons kept the plants growing and reproducing, the plants furnished the fish with food for growth and reproduction, and the fish furnished men with a livelihood and the herons with food. Thus, you see, there was a delicate balance between heron, fish, and water plants. The fishermen's mistake was to destroy this balance.

MISTAKE NO. 2

You have seen pictures of the African or Brazilian jungles. What a mass of plants and animals growing in apparent disorder! Everything appears just to grow. But that is not so, as the Boers, early Dutch settlers in Africa, found out.

They sent out hunting expeditions to kill the meat eaters—lions and leopards, which sometimes took one or two of their livestock. Animals which eat meat are called carnivorous animals, or *carnivores* (kär′nĭ vōrz). What happened? In some communities the hunters did a good job and killed most of these carnivores. As a result the grazing animals, or *herbivores* (hûr′bĭ vōrz, Fig. 67), deer and antelope, giraffe, wild boars, and rodents, which were kept down by the carnivores, reproduced in great numbers. They ate up the natural vegetation in the community and then they began to attack the farmers' crops.

In one area the herbivores made farming impossible and the Boers had to leave. So the Boers learned to leave the balance between the carnivores and their prey, the herbivores, alone. They did this even though it meant that some of their cattle would be eaten. They learned that the jungle represents a delicate balance between the plants, the animals that eat the plants, and the carnivores that feed on the grazing animals. One living thing lives on

68

The gypsy moth. Placed in a new environment where its natural enemies did not exist, this insect caused tremendous destruction. (Yale Peabody Museum of Natural History)

another. The idea is summarized in an old rhyme:

> Big fleas have little fleas
> Upon their backs to bite 'em.
> And little ones have lesser ones,
> And so ad infinitum.

The jungle is one large community, each living thing fitting into its proper place. Carnivores eat herbivores, herbivores eat plants, while green plants make their own food from the soil, water, and air.

OTHER MISTAKES

In South Africa, man made the mistake of destroying the balance between plants and animals by removing one or more animals. Suppose he were to introduce an animal into an environment where it had never lived before and allow it to compete with the animals and plants already living in balance. What would happen then?

Leopold Trouvelot, a New Englander, brought the gypsy moth to this country from France in 1869. He wanted to breed a better silkworm moth. Unfortunately, some of the moths escaped. By 1900, they had become a scourge in the New England area, eating their way through orchards, stripping shade trees of all their leaves, dropping on townspeople, even crawling into houses. Today, although they are being combated, they have not yet been brought under control (Fig. 68).

In Laysan, an island in Hawaii, a pair of rabbits was introduced in 1902. By 1923, thousands of rabbits, descendants of the original pair, had practically stripped the island of its vegetation. Even huge trees toppled as the rabbits ate the bark at the base of the trees.

You now have enough evidence to realize how serious it is to upset the balance between plants and animals. A balance between plants and animals is a result of thousands of years of growing and living together. Although there are countless plants and animals, they are governed by two principles: First, they are adapted to the environment in which they live; second, they live in a balance in that environment. These principles apply to elephants, to Baltimore orioles, to men, to wheat, to bamboo, to mosses, to bacteria—to all living things.

ORDER OR CHAOS?

In this brief account, you must have been impressed with the fact that there are great numbers of animals. It is discouraging to be reminded that there may be 1,000,000 different kinds of animals and 350,000 kinds of plants. How is it possible to learn the habits and the structure of a few hundred, not to speak of a million? It is possible because large groups of these plants and animals are similar in their activities and structure. But are these similarities important? Do they really help us understand all these plants and animals? Suppose you do a bit of exploring in your own environment and see for yourselves.

EXPLORING YOUR ENVIRONMENT

Why not invite a few friends to go on an expedition? Take some jars of various sizes with you. If you have an old pillowcase, take that too. You may come across some harmless snakes you will want to have for the school museum. Also take a dip net and a metal can in which you can store plants so that they keep fresh and moist. Be sure to take a notebook.

LIFE NEAR A POND

Let's strike out through the woods and try to find a small pond. Wherever we see willows or red maples growing, we may expect wet ground, possibly a pond. So let's look for these trees. After a short walk we find a small pond, no larger than a few acres, or a large city block.

As we approach the edge of the pond, we hear soft "plops" as animals jump into the water. As you might guess, they are frogs. But right now let us give our attention to sunfish which are in the shadow of a rock (Fig. 69). We catch some with our nets, for sunfish are fine for the school aquarium. We also take some of the water plants to stock the aquarium.

CLASSIFYING AN ANIMAL

How do you know sunfish are fish? Quickly you will point out that sunfish have fins, gills, and scales. Most fish have these characteristics. But reptiles such as snakes, turtles, and lizards have scales too. However, reptiles have no gills and fins. You see it is possible to know a good many animals by grouping those which have the same characteristics. When a scientist places living things with similar characteristics in one group, he is *classifying* them. For instance, all animals with fins, gills, and scales are classified in one group as *fishes*, and all animals with feathers are classified as *birds*.

If someone in Africa reported that he had found a fish two feet long, you would know a good deal about its structure, where it lived, how it breathed. If you had dissected a fish, you would also know, in general, the appearance of the inner organs of the fish found in Africa. You would be able to do this even though you had never seen it.

69 *Fins, gills, and scales are fish characteristics. Are all three shown in this picture? (American Museum of Natural History)*

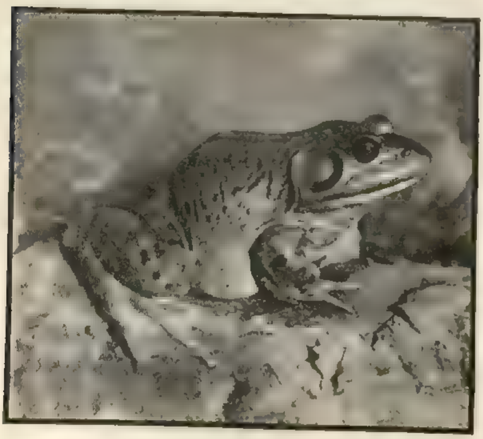
Let us get along with our trip and see what other kinds of living things we can find.

FROGS AND THEIR RELATIVES

Look at the frog sitting on a rock at the edge of the pond (Fig. 70). Notice his glistening moist skin. Frogs breathe partly through their skins and partly by pushing air into their lungs. If you look closely, you can see the frog's throat going up and down. When his throat goes down, air comes into his nostrils. Then he closes the nostrils, the throat goes up, and the air is pushed into the lungs.

The frogs' eggs have already hatched, but there are some tadpoles. If you bring a frog and some tadpoles into the laboratory, you can watch the tadpoles develop into frogs.

How do we recognize frogs? They have smooth, moist skin and four legs. They lay their eggs in jellylike masses in water. The young, called tadpoles, live in water while the adults live on land. They belong with the salamanders and toads to a group of animals called *amphibians* (ăm fĭb′ĭ ănz). Amphibians live part of their lives in water, as tadpoles, and part on land, as adults.



70 *The frog, an amphibian animal, lives the early part of its life in the water and the adult part on land. (American Museum of Natural History)*

71 *A garter snake, a reptile. How do reptiles differ from amphibians? (American Museum of Natural History)*

Salamanders, the tailed relatives of frogs, are usually found in the same environment. By turning over flat rocks, you may find the spotted salamander (black with yellow spots) or the red salamander (a reddish color). Keep any you find in a covered jar in which some wet mosses are placed. Both the frog and salamander will eat worms and insects.

WE COME ACROSS SOME REPTILES

As we continue lifting rocks, we see worms, beetles, crickets, and spiders. Under another rock, we find a garter snake (Fig. 71). It can't bite if grasped around the neck. In the school laboratory, you can keep the garter snake alive by feeding it worms, insects, and small frogs.

Notice the hard scales on these *reptiles*. All reptiles have such scales. Some reptiles lay eggs with shells. Others hatch the eggs inside their bodies, and the young are born alive. Reptiles do not sit on their eggs. They generally lay them in a place where the sun will warm them and hatch them.

Most snakes are not poisonous. Poisonous snakes like the rattlesnake, copperhead, moccasin, or coral snake will not attack if they are left alone. Can you distinguish a poisonous snake from a nonpoisonous one? If not, study Fig. 72 very carefully.

It has been fairly easy to collect fishes, amphibia, and reptiles. These are cold-blooded animals and, except for the fishes, are fairly sluggish in their movements, especially in cool weather. If you take their temperature, you will find it is just about the same as the temperature of their environment.

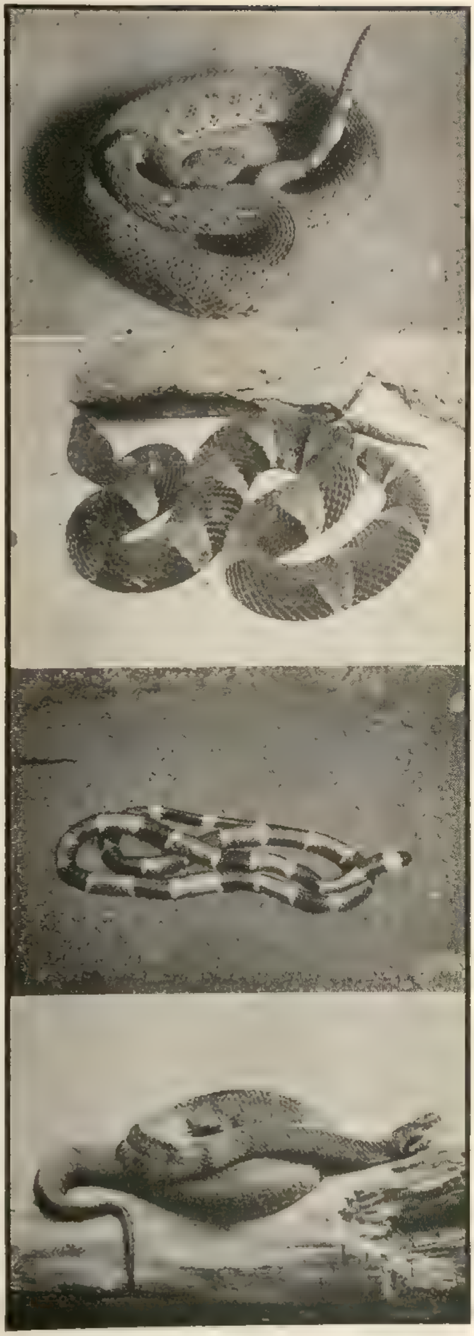
WARM-BLOODED ANIMALS

The warm-blooded animals, birds and mammals, are on the other hand, hard to catch. They are quick, and they have bigger brains than the cold-blooded animals. But there is no need to collect them, for you are quite familiar with their characteristics.

You can recognize any member of the bird group by its feathers, by its warm body, and by the fact that the female lays eggs. A member of the *mammal* group has hair or fur; it is warm-blooded, and it suckles its young with milk produced from its *mammary* glands. Squirrels, dogs, bats (Fig. 73), cows, whales, and man are just a few of the thousands of mammals.

ANIMALS WITHOUT BACKBONES

What of the other animals we found under the rocks? We saw earthworms, beetles, centipedes, spiders, and in the water we found snails and crayfish. To what groups do these animals belong? Although they appear to differ greatly, they have several things in common. They have no backbones and no internal skeletons as do fishes, amphibians, reptiles, birds, and mammals. Animals with backbones, like the rep-



72 *Common poisonous snakes. Top to bottom: red diamond rattlesnake, Southern copperhead, coral snake, cottonmouth or water moccasin. (American Museum of Natural History)*

73

A bat. Some people mistake bats for birds. But bats, like whales and dogs, are mammals. (American Museum of Natural History)

tiles and mammals, are called *vertebrates* (vûr'tê brâts). Animals without backbones, like the earthworms or insects, are called *invertebrates*.

You see that even this short exploration around a pond has revealed to you the major characteristics of the main groups of vertebrates: fishes, amphibians, reptiles, birds, and mammals. And you also know that lack of a backbone is the major characteristic of the large group of invertebrates. We will leave the study of invertebrates to your later courses in science.

NAMING PLANTS AND ANIMALS

It is both useful and satisfying to know the names of the animals and plants you come upon. But just knowing that a plant is a fern or moss doesn't satisfy you; you want to know which fern or moss it is. Knowing it is a bird is not enough. Which is it? Robin, bobolink, kingbird, or yellow-throated vireo? Which frog is it? Bullfrog, grass frog, pickerel frog, or spring peeper?

Naming the plants and animals is the job which faced Carolus Linnaeus and his friend Peter Artedi, in the eighteenth century. Together, they set about giving each animal and plant two names. The two names tell what kind, or species, of animal or plant any specimen is. Their system is a very valuable one, as you will see.

Where you live, do you find bitterweed, wild tansy, hayweed, hogweed, wormwood, stammerwort, or carrotweed? All these are different names for ragweed; it has different names in various parts of the country. All these names for the same plant make for confusion.

For scientists and those who want to be accurate we have the system originated by Linnaeus and Artedi. Two Latin names are given to each living thing. Latin is used because it has been for many centuries an international language known to scientists everywhere. Since Latin is no longer the language of any living people, its words are no longer changing form or meaning. Therefore, we can be certain that a Latin name used now will remain as it is and will be recognized by scientists everywhere. Our common ragweed is *Ambrosia trifida*, and people who are familiar with the system know what we are talking about, whether they are in England or Brazil.

At the moment, you need not learn these Latin names. Instead, suppose you learned the name of just one new living thing each week. In a year you would know about fifty! In several years you would be an expert on the living things in your area. In "Living Things as a Hobby" (p. 134), you will find reference to books which give you the description of the habits and the specific names of a good many of the living things you will find in your environment. Why not start now?

INVISIBLE WORLDS

Start your project of learning the names and habits of the living things around you by filling a jar with pond water and waterweeds. Add a little bit of mud from the bottom of the pond. In the school laboratory, open the jar and let it stand for a few days. Under a microscope, examine a drop of water from the film on the top of the jar. You will discover a whole new world. In that drop of water you may find slipper-shaped animals, whirling about (Fig. 74). You may see these animals moving, feeding, and perhaps you will find one dividing in two. How can you go about learning what they are? First, make careful drawings. Then compare your animals, or drawings, with the figures in the outline which has been prepared for your use in "Living Things as a Hobby." Use of this outline soon helps you to name the slipper-shaped animal as *Paramecium* (păr′ȧ mē′shĭ ŭm). As you learn to use the outline and the books to which it refers, you will be naming many of the other living things in your pond or stream, in the woods, and in your neighborhood.

MORE CHARACTERISTICS IN COMMON

All living things, or organisms, as we shall call them, have many things in common. How do you distinguish between a living thing and a nonliving thing? Why don't you mistake a rock for a living organism? The answer lies in the ability of living things to do certain things which nonliving things cannot do. For instance:

1. All living things reproduce their own kind.

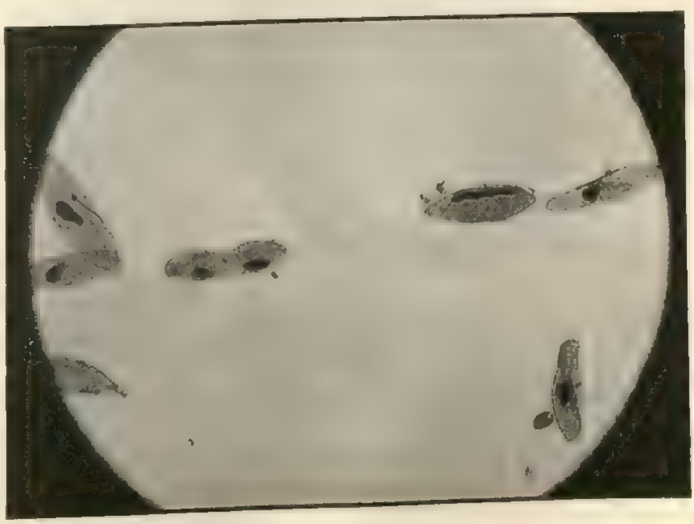
2. All living things use food.

3. All organisms grow. Nonliving things do not.

4. Animals move about. Even plants move different parts of their bodies as they grow.

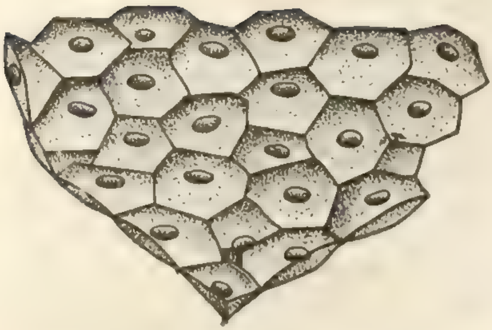
5. All organisms respond to their natural environment. A plant's leaves grow toward the sun, and its roots grow toward water. Animals react to the smell of food. You may react to the sound of a bell; you certainly react when your name is called.

6. Living things have definite forms. A piece of granite rock may be wedge-shaped, round, or square, or it may be a statue, but it is still granite rock. All

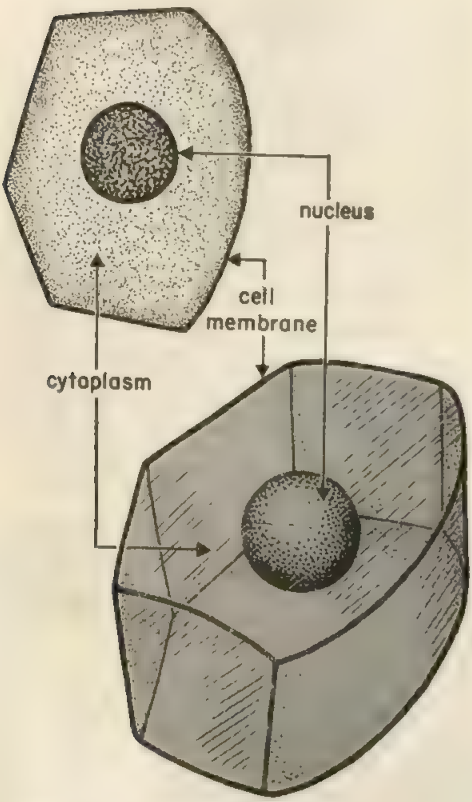


74

Paramecia. Put a drop of pond water under the microscope and see if you can find some of these microscopic animals. These animals have been stained so that you can see their nuclei. Can you see one dividing? (General Biological Supply House)



75 *Frog's skin. Each small diamond-shaped structure is a cell.*



76 *A drawing of a typical animal cell. Each cell is really a small cube or sphere. What are the three important parts of a typical cell? Plant cells have an additional structure outside the cell membrane, called the cell wall.*

squirrels have definite forms, so have all beech trees, all snails, all men. Living things have a definite characteristic structure or *organization.*

ALL ORGANISMS HAVE A BASIC STRUCTURE

Let us go further. Let us examine the structure of some organisms by means of a microscope. When a frog is placed in an inch or so of water in a jar, it sheds its skin easily. Let us take a bit of the skin and stain it with iodine. This makes it easier to examine with the microscope. We find it is made up of thousands of small structures which look like those in Fig. 75.

Now take a toothpick and scrape the inside of your cheek. Put the scrapings on a drop of water on a slide. Now add a drop of iodine. Again we see structures very similar to those we saw in Fig. 75.

Finally, let us peel off a bit of onion skin, stain it with iodine and examine it. Again we see that the onion skin is made up of small structures that are oblong in shape. Many thousands of organisms have been dissected and studied under the microscope. The vast majority of them have been found to be made up of these structures.

As you may remember, scientists call these structures *cells.* Cells appear in a great variety of sizes and shapes, but they can be seen only under a microscope. The cells which make up your nerves are quite different from those which make up your muscles. No matter what part of an organism you examine you will find that it is made up of cells. The paramecium (p. 123) is made up of only one cell.

Each cell has a *nucleus* (nū'klē ŭs) near its center (Fig. 76) and is enclosed in a cell wall or membrane. Each cell is made up of the stuff of which all living things are composed. This living stuff is called *protoplasm* (prō'tō plăz'm).

Scientists do not yet know the exact nature of protoplasm. They do know that it always contains four elements: carbon, hydrogen, nitrogen, and oxygen. Protoplasm in one organism is different chemically from protoplasm in another organism. But protoplasm is the one living substance in the world. When an organism dies some change that we cannot yet identify takes place in the protoplasm.

Later on you will study how cells work (Chap. 31). Right now the important thing is to know that all living things are made up of cells and that the stuff cells are made of is protoplasm.

ORDER, NOT CHAOS

Next time you go out for a walk, look about you and use your new understanding of the similarities among organisms. Instead of emphasizing differences in the living things which are your neighbors, look for similarities.

There are a staggering number of living neighbors in this world: 1,000,000 different kinds of animals and 350,000 kinds of plants. You have a great deal in common with them.

GOING FURTHER

1 *Collecting living things.* Your major activity for this chapter is collecting and studying living things. A section "Living Things as a Hobby" (p. 134) is given over to this interesting activity. Would you like to be able to identify the common animals and plants? Do you want to learn how to keep and feed fish, frogs, lizards, snakes, birds, and even small mammals at home or in school? Then read "Living Things as a Hobby" and do what it suggests.

2 *Words are ideas.* Can you use these words in a sentence which will illustrate their meaning? Use the glossary.

adaptation	herbivores	amphibian
balance	environment	reptile
animal	classification	cell
plant	invertebrates	nucleus
competitors	vertebrates	protoplasm
carnivores	fish	life activities

3 *Put on your thinking cap.*

1. The problem of conserving our soil is a problem of keeping a balance in our environment. What facts are there for this statement?

2. We pay a constant tax to insects. What facts are there for this statement?

4 *Test yourself.* In your notebook match the number in front of each item in the left column with the letter of the item to which it is most closely related in the right column. Do not mark this book.

1. mammal	A. turtle
2. invertebrate	B. salamander
3. fish	C. monkey
4. carnivore	D. a type which eats vegetation only
5. amphibian	E. man's chief competitor
6. herbivore	F. has gills
7. reptile	G. a type which eats meat only
8. insect	H. fitted to the environment
9. balance	I. carnivores and herbivores flourishing together
10. adaptation	J. spider
	K. starling

5 *Men and women wanted.* Many men and women have spent their lives contributing to science as taxonomists (tăks ŏn′ ō mĭsts) or ecologists (ē kŏl′ō jĭsts). A taxonomist is an expert in identifying plants and animals. (Don't confuse him with a taxidermist, who preserves an animal's lifelike appearance by stuffing and mounting the skin of the animal.) An ecologist is an expert in understanding how plants and animals affect each other and their environment and how their environment affects them in turn. Show an ecologist a plant or an animal and he will be able to tell you in what kind of environment it lives. Admiral Byrd's expedition had several taxonomists and ecologists to study the living things in Antarctica.

Many boys and girls start on the road to becoming taxonomists or ecologists by taking up the hobby of knowing and collecting plants and animals (see "Living Things as a Hobby," p. 134).

ASTRONOMY AS A HOBBY

Astronomy is fun, if you take it seriously. That's not strange. The only way to learn enough about anything to enjoy it is to take it seriously. This is true of dancing, of stamp collecting, of sailing a boat, and it is certainly true of astronomy. The purpose of this section is to persuade you that the serious study of astronomy may lead you on to a profession or to a pleasant hobby.

On a clear, starlit night an astronomer is an interesting companion. At such times, he may entertain and amaze you with his knowledge of constellations and galaxies (Chap. 4). But that is not his real work unless he happens to be a teacher of astronomy. The real work of an astronomer is done with instruments and with paper and pencil. He is a mathematician, a photographer, and a detective. He is also a student of physics. However, his interest in astronomy, like your own, may have begun on a star-studded autumn night. So let's imagine ourselves outdoors on such a night in a place where no glow of city lights will dim the splendor of the sky.

WHO'S WHO IN THE SKY

As you look around the sky, do you see a horse with wings, a couple of bears with long tails, a lady in a chair, and another lady in chains? Do you see a couple of fishes, each with a ribbon tied to its tail? Do you see a crow standing on the back of a serpent? Do you see the hair of a queen? Can you find a lion, a crab, a dog, a goat, and a ram? Do you think all this is a joke? On the contrary, these are descriptions of some of the star groups or constellations that astronomers have been observing for thousands of years (Fig. 77).

To be perfectly sincere, we must admit that it is rather difficult to distinguish these figures in the sky. It is as though a stranger to our shores were to attempt to recognize Mount Washington from a photograph of General Washington. We believe that the ancients who named the constellations did it to honor their heroes rather than because of resemblances to persons or animals. To a modern astronomer, a *constellation* is not merely a star pattern but an entire area of the sky. Just as a geographer first divides the surface of the earth into continents, the astronomer divides the sky into constellations.

You can locate only a few of the 88 constellations at any one time because only about half of the total sky is visible from the place where you are standing. But if you wait a little while, the earth will turn and you will

see other stars that will be overhead in the early evening a few months later. However, if you observe the stars every night at the same time for a year you will be able to see all the stars visible from your latitude. To see the rest of the sky, you would have to go to the Southern Hemisphere and repeat your night watches.

All this trouble can be easily avoided if you live in one of six cities: Chicago, Philadelphia, Pittsburgh, Los Angeles, New York, or Chapel Hill, North Carolina. All six cities have projection planetariums, the one at Chapel Hill being the most recently opened. In these dome-shaped buildings the stars are represented by tiny points of light thrown onto a white ceiling. As the position of the projector is changed, you view the skies of both hemispheres for an entire year within a few minutes. A visit to a planetarium is a must for anybody fortunate enough to be near one (Fig. 78).

SIGNPOSTS IN THE SKY

The navigator on a ship or an airplane cannot rely upon a lecturer to point out the stars to him. He must know their location and recognize them in other ways. There are 55 special stars known as the navigation stars. To find all of them and to learn their positions at the various seasons, you will have to study one of the guide books listed at the end of this section. But some of the stars are not too difficult to locate. Let's try to find a few that every boy and girl should know.

Of course, you have heard of the North Star, called Polaris, because it is almost directly above the North Pole of the earth. To find it, look for the pointers. These are the two stars in the outer part of the bowl of the Big Dipper. Anyone can spot the Big Dipper because it really looks like a dipper. Follow the pointers across the sky about five times the distance between them and there you'll see a bright star. That is Polaris (Fig. 77). It is the last star in the handle of the Little Dipper. The Big Dipper is part of the constellation known since ancient times as the Great Bear (Ursa Major). The Little Dipper is the constellation known as the Little Bear (Ursa Minor).

Once you have found the Dippers and Polaris, you can use them as guides to locate some of the other constellations and navigational stars. Let your eye continue on across Polaris, following the line of the pointer stars. Presently, you will see a great square of four brilliant stars. This is part of the constellation of Pegasus (pĕg′ȧ sŭs), the Winged Horse (Fig. 77). It is one of the unmistakable signposts in the sky. Between Polaris and Pegasus is a W-shaped constellation. This is called Cassiopeia (kăs′ĭ ō pē′yȧ), the Lady in the Chair (Fig. 77). It is easy to find constellations if you know a few to use as guides. Try to find some more of the constellations shown in the star chart in Fig. 77. Then go star and constellation hunting in the sky.

THE MOTIONS OF THE FIXED STARS

The stars you see in the sky appear to you in almost exactly the same positions as they appeared to the ancient astronomers of Egypt thousands of years ago. Actually, all the stars are in rapid motion. They are traveling across the sky in every direction. For example, the star Vega is heading straight for us at the rate of nine miles per second.

Like the sun, the stars appear to travel across the sky, rising in the east and setting in the west. This is an illusion caused by the motion of the

77 *Star chart showing the patterns that men over the ages have made in their minds by grouping the stars. The northern horizon is at the top of the map.*

earth on its axis. Stars also appear to twinkle. This too is an illusion caused by the motion of the earth's atmosphere. It is like the motion of the wall behind a hot stove, a trick played on our eyes by the bending of the light rays as they come through the hot, moving air.

METEORS AND METEORITES

On any clear night, you may see the so-called shooting stars that streak across the heavens and disappear. These flashes of light are not caused by stars at all but by bits of stone or metal that happen to enter our atmosphere at high speed. Astronomers call these shooting stars *meteors*. If they land, they are called *meteorites*.

If you journey to Meteor Crater in Arizona, you will see what may happen when a large meteor becomes a meteorite. You will see a crater three-quarters of a mile in diameter with walls 600 feet high. It looks like one of the craters on the moon. Nearby are many fragments of iron meteorites. The main mass of the meteorite has never been recovered. All around, the limestone rock of the region is powdered as if struck by a colossal hammer. An even larger crater is reported to have been made in a remote part of Siberia on June 30, 1908. In 1950

Sky as seen from New York at 2 A.M. on October 5 is shown on the opposite page. Sky seen from same spot at 2 A.M. on April 30 is shown above.

another, larger crater (about 10,000 feet in diameter) containing a lake was discovered in northern Quebec.

Admiral Peary brought back to the United States the largest meteorite ever exhibited. It is the great Ahnighito (ä′nĭ gē′tō) Meteorite weighing 36½ tons and now on view in the Hayden Planetarium in New York City. This meteorite is iron, but some are more like stones and a few, called *tektites*, are rather like glass (p. 92). Tektites are especially interesting because of the theories about their origin. Some astronomers believe they may be chips of the moon which were dislodged by the impact of meteorites upon the moon.

MAKING A DATE WITH A COMET

No one can guarantee that you will see a meteor in a certain portion of the sky at a certain time. Nevertheless, meteors are not entirely unpredictable. We know that at certain times of the year, particularly in August and October, swarms of meteors will be seen. These meteor showers or swarms travel about the sun in orbits identical with the orbits of known comets. This seems to establish a close relationship between these two sky objects.

Comets have been known since earliest times. They have tails which stretch millions of miles across the sky. The great comet of 1843 was said to

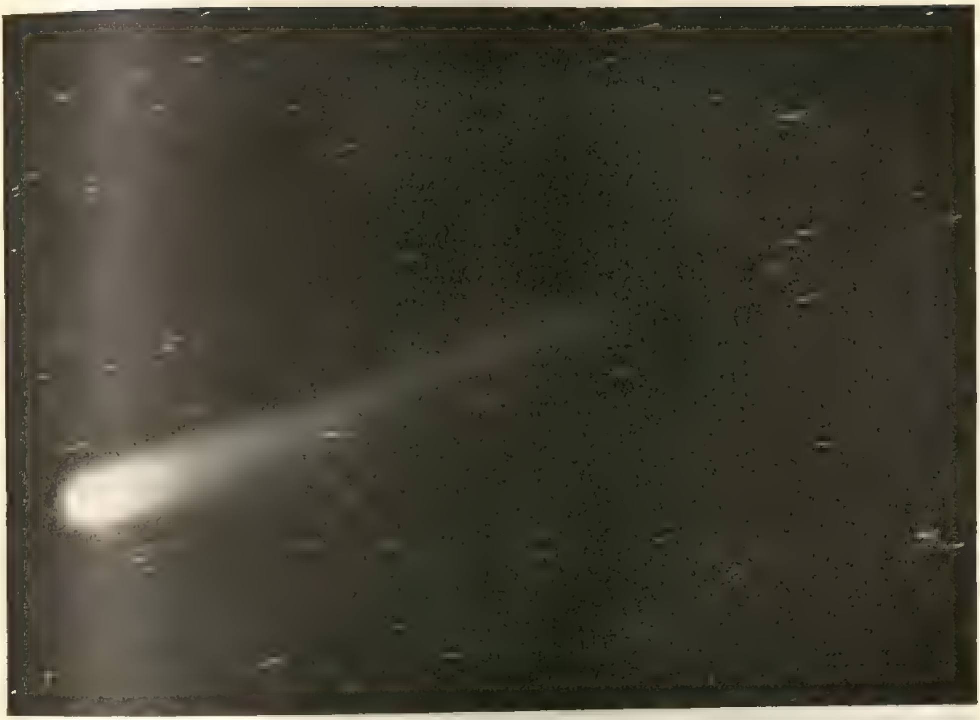
have a tail 200,000,000 miles long. Halley's Comet, last seen in 1910, had a tail 40,000,000 miles long (Fig. 79). The tail is a glowing mass of gas but it is estimated that if all the material in the tail of a comet could be condensed and gathered together, it would fit into an ordinary suitcase. At any rate, the earth has passed through the tails of comets many times without the slightest effect.

The impact of the head of a comet would be another story. Many scientists believe that the crater in Arizona may have been caused by the impact of a comet's head. It is likely that the head or nucleus of a comet consists of meteoric material. It is probably not a solid mass, but may consist of separate pieces something like a load of buckshot. In any event, it does not disappear like the tail. The head of a comet like Halley's travels on a long oval orbit. As it approaches the sun, the tail gets longer and longer. What causes this to happen is not known although there have been many guesses. The tail always points away from the sun, the head is nearest it. A halo of light also appears around the head of the comet and adds to its grandeur.

This halo of light makes it possible for astronomers to track comets as they approach and retreat from the sun. The astronomer who is able to discover a new comet or calculate the orbit of an old one usually has the honor of having it named for him. The Donati Comet

78

Inside a planetarium after the room has been darkened. The instrument in the foreground throws small spots of light on the dome-shaped ceiling. You seem to be looking at real stars in the sky at night. (American Museum of Natural History)



79 *Halley's Comet in 1910. The little streaks of light in the background are star trails made as the earth turned on its axis during the time the picture was being made. What evidence is there here that a comet's tail consists of very little material? (American Museum of Natural History)*

of 1858, Brooks's Comet of 1893, Morehouse's of 1908, and Cunningham's of 1940 are a few that have been named for their discoverers. Probably the most famous of all comets is Halley's. Its first appearance was noted as early as 240 B.C. Halley in 1682 calculated its path and predicted its return in 1758. It came again in 1834 and in 1910. Add 76 years to 1910 and look for its return in 1986.

WHAT IS A TELESCOPE?

Even if you are a middle-aged person when Halley's Comet next appears, you'll probably be able to see it without a telescope. Unfortunately, however, many sky objects are not visible to the naked eye. Aristotle, Ptolemy, and Copernicus never saw the moons of Jupiter or the planets Uranus, Neptune, and Pluto. Nor did they know that the sun's surface sometimes has spots.

Not until 1608 was the simple secret of the telescope discovered by Hans Lippershey, a Dutch maker of eyeglasses. He observed that when two convex lenses of different sizes are held between the eye and a distant object, the object appears to be nearer than it is. Within a year, the news of this discovery had reached Galileo, the great Italian astronomer. He made his own telescope by mounting a pair of lenses in a simple tube. You can do as much with lenses your teacher may be able to give you. Galileo immediately saw the value of this instru-

80
Homemade reflecting telescope. This boy is an amateur astronomer. He enjoys his hobby more because he made his own telescope. Have you ever looked at the moon, the planets, or the stars through a telescope? (Popular Science Magazine)

ment for studying the skies. His observations of the moons of Jupiter and of sunspots with a telescope provided the first important evidence of the correctness of the Copernican Theory, which was outlined for you in Chapter 4 (p. 61).

You may conclude from this information that a telescope (Fig. 80) is chiefly a device through which astronomers look to observe sky objects. Although astronomers do look through telescopes a great deal, the real value of the telescope in modern times is threefold. Take, for instance, the new great telescope, with a reflecting lens 200 inches in diameter, on Mount Palomar in California. Such a telescope serves, first of all, as a pointer. It makes possible accurate measurement of angles and distances between sky objects. Second, it is a light gatherer. Its wonderful lenses and mirrors gather together and focus sharply the faint rays of light from distant stars upon the prisms of spectroscopes and other instruments used for the analysis of light. Thus we can learn the temperature and chemical composition of the stars. Finally—and possibly most important—such a telescope is the magnificent lens of a camera, the best in the world. By means of telescopes and time exposures, astronomers take pictures of portions of the sky entirely invisible to the eye. Discoveries of stars too cool to give out visible light are made by photographs taken with infrared rays. The planet

Pluto was discovered in 1930 by comparing photographs of the part of the sky in which it was thought to be. The new 200-inch telescope will be used to take photographs of the sky. They will extend our knowledge of the universe to a distance of one billion light-years. This is just twice as far as we have been able to explore with the aid of the 100-inch telescope on Mount Wilson. Keep your eyes open for accounts of the discoveries made by astronomers who have made their hobby their lifework.

TAKING UP WHERE WE LEFT OFF

Now do you want to make your own telescope? We do not have the space to describe the method here, but *Amateur Telescope Making* by Ingalls, in the list of references at the end of this chapter, will be most helpful to you.

Do you want to make your own observations of the sky? Would you like to identify the different constellations? The sky chart on pages 128 and 129 will help you. Also, you will want to have some of the books described in the reading list, especially numbers 1, 2, 3, and 4.

Now you are on your own. Your success depends upon your own interest and your ability to work.

GOING FURTHER

1 *Building a telescope.* Build your own telescope for observing the stars. If you live in one of the cities where there is a planetarium, go to the curator for advice. If the planetarium does not offer its own course in telescope making, the curators will be able to tell you where to obtain proper instructions. For those who live elsewhere, a letter may be sent to the editor of the magazine *Sky and Telescope*, Harvard College Observatory, Cambridge 38, Mass. He will be able to advise you according to the type of telescope you wish to make.

2 *Building a sundial.* Build a sundial and set it up in your back yard or on a rooftop. Information on the building of sundials may be obtained by sending to the Superintendent of Documents, Washington 25, D.C.

3 *Celestial navigation.* Obtain the book *An Introduction to Celestial Navigation* by William H. Barton, Jr. from the Hayden Planetarium, New York 24, N.Y. (50 cents). Study this book and do the activities suggested in it. You will find it fascinating to explore the possibilities of becoming a navigator. For those who succeed there are many vocational opportunities. This book is for advanced students of astronomy.

Reading for the Amateur Astronomer

1. *A Field Book of the Stars* by William T. Olcott, Putnam, 1920. This book gives a description of 45 constellations grouped by the seasons during which they may be seen to greatest advantage. It also contains an excellent list of star names and their meanings.

2. *Star Lore of All Ages* by William T. Olcott, Putnam, 1911. This is a collection of myths, legends, and facts concerning the constellations of the Northern Hemisphere. It has 164 illustrations.

3. *The Book of the Stars for Young People* by William T. Olcott, Putnam, 1923. This book is helpful to beginners who want to learn the names of the stars.

4. *A Beginner's Guide to the Stars* by Kelvin McKready, Putnam, 1924. This book offers instruction in how to observe the stars and contains 12 charts with keys to observing the sky at various seasons.

5. *A Nature Trail in the Sky* by Frank E. Lutz, American Museum of Natural History, 1926. An inexpensive fifteen-page booklet that takes you on an interesting field trip among the stars.

6. *Astronomy*, Merit Badge Handbook, Boy Scouts of America (25 cents). A well-illustrated booklet for the student scout who intends to take his astronomy seriously

enough to earn a merit rating. It will help any student find his way about the sky.

7. *Amateur Telescope Making* by Albert G. Ingalls, Scientific American Publishing Co., 1935. This book contains practical information that will help you to build your own telescope.

8. *Handbook of the Heavens* by Hubert J. Bernhard, Junior Astronomy Club, American Museum of Natural History. If you are determined to become an expert in astronomy, you will be able to learn a great deal about charting the sky.

9. *Sky and Telescope*. This is a magazine published monthly. It contains feature articles on astronomy and gossip of the doings of professional and amateur astronomers. Subscribing to it and reading its articles will keep you posted on what the well-informed astronomer is doing.

10. *Astronomy* by Arthur M. Harding, Garden City Publishing Co., 1935. A book written for the layman. It contains much of the interesting history of astronomy and explains in a simple way many of the fascinating sidelights of astronomy.

LIVING THINGS AS A HOBBY

Most people who see a strange new living thing for the first time ask, "What is it?" You have asked this question yourself. Once you know the name of the organism you can go to various references given at the end of this section and discover how to keep it for further study. Or you may want to preserve a specimen that you have captured and display it in your private or school museum. In this section, therefore, we are going to introduce you to a method of learning how to name living things.

As you know from your reading in Chapter 7, living things can be placed in groups. Thus all fishes may be grouped together. But there are still larger groups: all plants belong to the plant kingdom; all animals belong to the animal kingdom. The animal and plant kingdoms are then divided into groups of organisms.

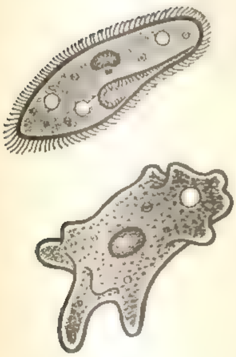
Each organism has special characteristics which place it in the group to which it belongs. For instance, all birds have feathers. Insects have six legs and generally have wings. Once you know the group to which an organism belongs you are well on your way toward finding out its name and its habits.

We are going to help you learn the scientific way of classifying and naming the plants and animals. On the following pages you will find descriptions of the major groups of plants and animals, accompanied by drawings of some of the more important members of the group. This will help you recognize some of these organisms. After all, the organisms in any one group are similar to each other in many respects.

At the end of this section is a reading list which suggests many books of interest to the amateur naturalist. These books have further information on the the collection, naming, and preservation of organisms in each group. The numbers given after each of the following descriptions indicate which books in the reading list will give you the most information about the group.

ANIMAL KINGDOM

INVERTEBRATE ANIMALS



81
(above) Paramecium
(below) Amoeba
(both microscopic)

Single-celled animals. (Fig. 81) In this group, you will find microscopic animals made up of one cell.

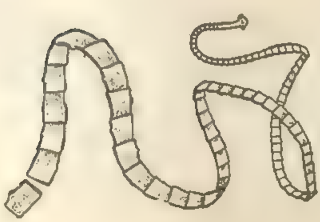
Some single-celled animals, like *Paramecium*, move about by means of tiny hairlike structures. Others, like *Amoeba*, send out projections of the body and seem just to flow along. (1, 10, 11)

82
Sponge

Sponges. (Fig. 82) You have probably used the common bath sponge (not the artificial rubber sponge). This bath sponge is the skeleton of an animal which lives on the bottom of the ocean. It takes in food through pores in the body. (1, 10, 11)

83
Jellyfish

Cup animals. (Fig. 83) These animals are generally cup-shaped or umbrella-shaped. The jellyfish and sea anemones belong here. Most of the animals in this group are to be found living in the ocean. The animals have batteries of stinging cells in their waving, armlike tentacles. When a small animal touches these tentacles, it is paralyzed by the stinging cells. It can then be eaten by the cup animal. (1, 10, 11)



84
Tapeworm

Flatworms. (Fig. 84) These worms are what their group name states—flat. The tapeworm and liver fluke, both of which infect man, are in this group. The worm *Planaria*, commonly found in streams, is also found in this group. (1, 10, 11)

Roundworms. (Fig. 85) The smooth, round worms like the common "vinegar eel" (found in vinegar) and the common horsehair worm belong here. The hookworm and trichina are also roundworms. (1, 10, 11)

85
Hookworm

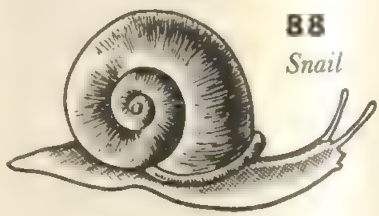
Ringed worms. (Fig. 86) The common earthworm and sandworm belong to this group. The animals of this group have bodies which appear to be made of rings or segments. However, don't mistake a millipede for a ringed worm. Ringed worms have no legs like the millepede (whose body is also made up of segments). (1, 10, 11)

86
Sandworm

Spiny-skinned animals. (Fig. 87) In this group you will find the starfish, sea urchin, and sand dollar. All of these animals have a spiny skin or a hard outer shell. (1, 10, 11)

87
Starfish

Soft-bodied shelled animals. (Fig. 88) In this group, you will find the oyster, clam, snail, slug, squid, and octopus. Most of the animals in this group have two shells like the clam, or a spiral shell like the snail. The squid and octopus have a straight shell within the body. (1, 10, 12)



88
Snail

Joint-legged animals. (Fig. 89) This group has the greatest number of animals. All of them have legs made up of joints. In this group you will find:

Crabs, lobsters, and their relatives (with five pairs of legs).

Centipedes and millepedes with many legs.

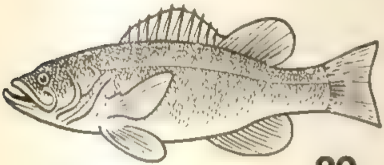
Insects with three pairs of legs. Most insects have wings.

Spiders with four pairs of legs and no wings. (10, 11, 13, 14, 15)

89
Fly

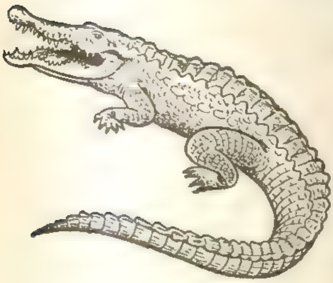
All the animals belonging to the groups about which you have just read are fundamentally different from you in that they have no internal skeleton and no spinal cord; they are called invertebrates. Animals with internal skeletons are vertebrates. A human being, a cat, and a lion are vertebrates.

VERTEBRATE ANIMALS



90
Fish

91
Frog



92
Crocodile

93
Bird

94
Cat

Although all the vertebrates belong to one group, it is divided into several subgroups. For example:

The fishes. (Fig. 90) These are animals with scales and fins. As you know, they live in water. (1, 16)

The amphibians. (Fig. 91) Frogs and salamanders belong to this group. The adults generally live on land, but lay their eggs in water. The young live in the water until they become adults. (1, 10, 11, 17)

The reptiles. (Fig. 92) Snakes, turtles, lizards, alligators, and crocodiles belong to this group. These animals have scales and most of them lay eggs with shells. (10, 11, 18, 19)

The birds. (Fig. 93) These animals are warm-blooded, and have feathers and wings; they lay eggs with shells. (20, 21, 22, 23)

The mammals. (Fig. 94) The furred warm-blooded animals belong to this group. In most mammals microscopic eggs develop into young within the mother's body. The young are fed milk from mammary glands. The mammals also give their young great care.

Within the mammal group are such strange animals as the duckbill, or platypus, which unlike other mammals lays hard-shelled eggs outside its body. However, it suckles its young like other mammals.

You, of course, are a mammal. (10, 11, 24, 25)

PLANT KINGDOM

You can learn the names of plants in much the same way. In this book, we are going to classify all plants in five major groups.[1]

The five groups include some 350,000 kinds of plants. On the other hand, the various groups of animals include almost one million different kinds. This statement is not meant to alarm you. For in the area in which you live there is a relatively small number of animals and plants. Once you know the common plants and animals, you will find it less difficult to identify others as they come along.

The five major groups of plants are:

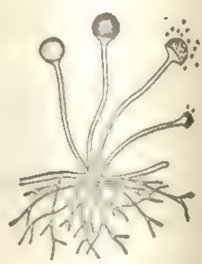
[1] As you go on in your study of biology, you will find that some scientists group the plants into four groups and others group them into five. For beginners, however, we think it better to group the plants into five groups.

Bacteria. (Fig. 95) These are microscopic, colorless, single-celled plants. Most of the bacteria are harmless, some are helpful, some cause disease. (Chap. 32)

95
Bacteria
(*microscopic*)

Simple-bodied plants. (Fig. 96) These plants have no roots, stems, or leaves. They are the common pond scums, soft, green masses sometimes found floating on the surface of ponds or streams. In a jar of water, a mass of these plants looks like a mass of fine, soft, green hair.

In this group also are the colorless plants, the fungi. Colorless here means lacking chlorophyll. Some fungi are blue, yellow, or red. The fungi include the mushrooms, bread molds, and blue molds. (1, 9, 10, and Chap. 32)



96
Bread mold

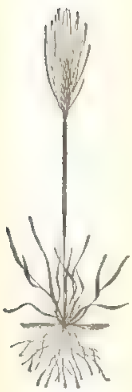
The mosses. (Fig. 97) The mosses are small green plants which live in a moist environment. There are two kinds of mosses. Some mosses, called liverworts, have flat bodies. Others have upright leafy bodies (like those in the accompanying drawing). All produce spores in a structure which looks like a tiny golf club. Spores are microscopic cells which reproduce the plant. (2, 10)

97
Moss

98
Fern

The ferns. (Fig. 98) Most of these plants are easy to recognize because of their characteristic leaves, or fronds, shown in the drawing. At certain times, the backs of the fronds produce spores. Ferns have underground stems and roots. (3, 10)

Club mosses and horsetails also are classified as ferns.



99
Wheat

The seed plants. (Fig. 99) The seed plants are the common plants you see about you. They generally produce flowers and seeds. Oaks, maples, oats, wheat, and corn all belong to this group. Other members of this group are the pines, hemlocks, and spruces.

There are several subgroups, the most important of which are:

Plants with flowers. The flowers may be small, as in the grasses, or large, as in the lily or magnolia.

Plants with cones. These are the plants with needle-shaped leaves, like the fir, pine, and spruce. Their seeds are found in cones. (5, 6, 7, 8)

You are on your way. This is the simple way in which the writers of this book began. It is the way many an expert on plants and animals began.

Ask your teacher's help in your study. Also get several of the references. In any event, if you begin this hobby now, you should be an accomplished naturalist when you leave high school.

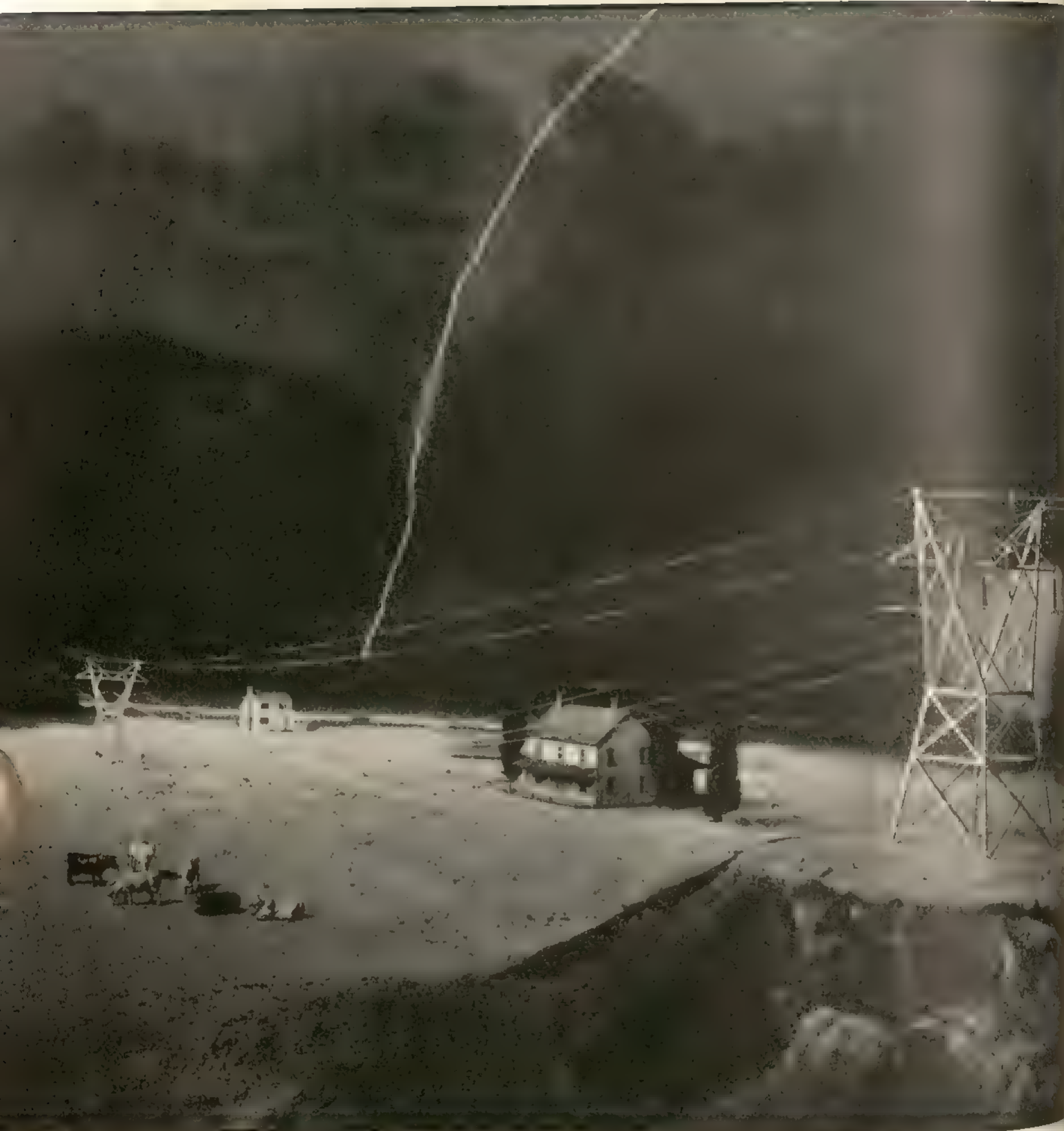
Reading for the Amateur Naturalist

1. *Field Book of Ponds and Streams* by Ann Morgan, Putnam, 1930.
2. *How to Know the Mosses* by E. Dunham, Houghton Mifflin, 1916.
3. *Ferns of Northeastern United States*, Macking Printing Co., Easton, Pa., 1936.
4. *Beginners' Guide to Wild Flowers* by E. Hausman, Putnam, 1948.
5. *The Book of Wild Flowers for Young People* by F. Schuyler Mathews, Putnam, 1923.
6. *Field Book of American Wild Flowers*, by F. Schuyler Mathews, Putnam, 1912.
7. *Wild Flowers* by Homer House, Macmillan, 1934.
8. *Field Book of American Trees and Shrubs* by F. Schuyler Mathews, Putnam, 1915.
9. *Field Book of Common Mushrooms* by W. Thomas, Putnam, 1928.
10. *Handbook of Nature Study* by A. Comstock, Comstock Publishing Co., Ithaca, N.Y., 1947.
11. *Parade of the Animal Kingdom* by Robert Hegner, Macmillan, 1935.
12. *A Field Guide to the Shells* (of our Atlantic and Gulf Coasts), P. Morris, Houghton Mifflin, 1947.

13. *The Butterfly Book* by W. J. Holland, Doubleday, 1931 (Nature Library).
14. *Field Book of Insects* by Frank E. Lutz, Putnam, 1921.
15. *How to Know the Insects* by J. E. Jaques, J. E. Jaques, Mt. Pleasant, Iowa, 1936.
16. *Field Book of Marine Fishes of the Atlantic Coast* by Charles Breder, Putnam, 1929.
17. *Handbook of Frogs and Toads* by A. A. Wright and A. H. Wright, Comstock Publishing Co., Ithaca, N. Y., 1933.
18. *Snake-Hunter's Holiday* by R. Ditmars and W. Bridges, Appleton-Century, 1935.
19. *Snakes of the World* by R. Ditmars, Macmillan, 1931.
20. *Field Book of Wild Birds and Their Music* by F. Schuyler Mathews, Putnam, 1921.
21. Sets of Colored Bird Cards (Spring, Summer, Fall, Winter), National Audubon Association.
22. *A Key to Birds' Nests* by A. A. Allen, Slingerland, 1929.
23. *Book of Birds for Young People* by F. Schuyler Mathews, Putnam, 1921.
24. *Field Book of North American Mammals* by H. E. Anthony, Putnam, 1930.
25. *Pets and How to Care for Them* by L. S. Crandell, New York Zoological Park, 1930.

UNIT THREE

UNDERSTANDING THE EARTH'S WEATHER



Can man control the weather? A miniature, man-made stroke of lightning on a miniature power line shows engineers how to protect real power lines against real lightning. The bolt harmlessly strikes the protective upper lines without damage to the power lines below. Preventing damage is one form of weather control. (Westinghouse)

The weather we do something about

Mark Twain was witty but wrong when he remarked that everybody talks about the weather but nobody does anything about it. The fact is everyone does something about the weather even if it is no more than to button up an overcoat in winter or to curl up under a shade tree in summer.

Actually much is being done about the weather. For example, look at this message: WA N SPL 1624E E30 ⊕ 15 ⦶ 2V TRW–BD–152/68/60→↘22 +↑1618E/ 996/ + ⊕ NW OCNL LTNG IN CLDS. It was written by men who are doing something very important about the weather. It is a weather report which was broadcast to all whose very lives depend upon accurate weather information—aviators and captains of ships at sea. Here is what it says: "Washington—observance of instrument flight rules required; special report at 4:24 P.M. Eastern Standard Time; ceiling estimated at 3000 feet; overcast, lower scattered clouds at 1500 feet; visibility two miles; variable; thunderstorm; light rain shower; light blowing dust; barometric pressure 1015.2 millibars; temperature 68° F.; dew point 60° F., wind west-northwest 22 miles per hour, strong gusts; moderate wind shift from south at 4:18 P.M., Eastern Standard Time; altimeter setting 29.96 inches; dark to northwest, occasional lightning in clouds." In this unit you will learn how weathermen make the observations which make such reports possible. You will learn also how to train yourself to read and understand such reports.

Doing something about the weather is everybody's business and it involves much more than being able to read weather reports, although that is important. It means obtaining at least an elementary knowledge of the science of meteorology (mē′tê ẽr ŏl′ ô jĭ), the study of weather changes. Meteorology is a science that has grown to great importance within recent years. Chiefly, this growth in importance is the

result of the invention of the airplane and the coming of the air age. Weather knowledge has become as necessary as knowledge of how to build airplanes or houses.

How much influence the science of meteorology will have upon the future of the world is still a guess. We live in an age of air power. Can there be any doubt that we need to know as much as possible about the air in which our planes fly?

Do you plan to build a house of your own? A house is, in one sense, a capsule of perfect weather. How are you going to keep your indoor weather perfect?

Do you plan to be a farmer? You will need to know enough about the weather to protect your livestock and plants. Good weather is the farmer's ally; it helps him produce record crops. Bad weather may ruin him. For instance, a sudden freeze in Florida may destroy the year's crop of oranges, grapefruit, and tomatoes. A drought in the Midwest may ruin the wheat or corn crop.

Bad weather may affect you in other ways. A tornado may destroy lives and property. Continued freezing weather in winter raises the fuel bill for everyone and may result in accidents and death. Continued high heat may also cause death.

Wherever you live, whatever you do, weather plays an important part in your life.

CHAPTER 8

OUR DAILY WEATHER

"Nice weather we're having," is a common enough greeting.

Whether we are enjoying October's bright blue weather or whether we are soaked to the skin by a rainstorm, we wonder what makes the weather. There is no simple explanation, for the weather is the product of many forces. Sometimes these forces produce hurricanes or tornadoes, weather so frightful that we find it almost beyond belief. At other times, these forces will produce mild, sunny weather with gentle breezes which invite us outdoors. However, at all times, the weather is caused by air in motion. What causes changes in the motions of the air? How does the activity or motion of the earth's atmosphere produce our weather?

In this chapter you will study the atmospheric conditions which are responsible for changes in the weather. In the next chapter, "Predicting Weather Changes," you will deal with different kinds of weather—mild winds and tornadoes, rain and snow, sleet and hail.

THE ATMOSPHERE

We live at the bottom of an ocean of air called the atmosphere. It is always in motion. When you have discovered what makes the air ocean move, you will be well on your way to understanding what makes the weather change.

AIR IN MOTION

To begin with, let's try to set just a roomful of air in motion. How would you do it? You might open a window and a door, creating a draft, or you might turn on an electric fan. Even the heat from an electric light bulb can start a circulation of air (Fig. 100). Have you ever noticed how the air seems to dance and quiver over a hot stove or radiator? Have you ever felt the draft caused by air rushing up the chimney when a roaring fire is burning on the hearth?

A simple experiment will show us what happens when air is heated. Take a flask and attach a rubber balloon to

100 *The motion of the air rising from the hot light bulb is revealed by the turning of the vanes. You can make a vane like the one shown from a piece of tin. One student used this device to detect drafts in his home.*

it by means of a glass tube fitted into a stopper. Now heat the flask. You will notice that the balloon expands. Why? You know that there is no more air in the flask and the balloon together when the balloon is expanded than there was before the flask was heated. It must be, therefore, that heating the flask causes air to expand. That is, heated air takes up more room.

Air is a mixture of gases. The gases we are concerned with are composed of small units called molecules. Most substances in the world are composed of molecules. Those in gases are widely separated from each other while those in a solid substance like granite are closer together. Molecules are too small to be seen under an ordinary microscope but scientists know that all molecules are in constant motion.

When a gas is heated, its molecules move faster and move farther apart. They take up more room. To put it another way, gases expand when heated. Air expands when heated. Furthermore, scientists know that when a certain volume of hot air expands it becomes lighter than an equal volume of cold air. Also, heated air rises when colder, heavier air moves in under it.

Now you know what happens to the air above a hot stove. It expands, becomes lighter, and rises as cold air moves in under it. Similarly, when the air in a fireplace is heated, it expands and rises as cold air from the room moves in under it. The movement of air into the fireplace and up the chimney creates a draft, or movement of air in the room. Now let us see what happens when air is heated over parts of the earth.

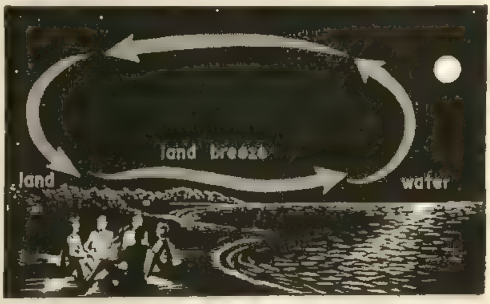
TEMPERATURE DIFFERENCES MAKE THE WIND BLOW

Suppose you visit the seashore on a summer day. You notice that a cool breeze is coming from the sea toward the land (Fig. 101). How do you account for the origin and movement of the sea breeze?

You can get some facts by feeling the sand on the beach and the water in the ocean. The dry sand feels hot, doesn't it? If you dip your feet into the water you think it is cold, even icy. Actually, the water is far above freezing—probably around 60 to 70 degrees on the Fahrenheit scale. By now you must know why the breeze is blowing from the sea toward the land. The sea is colder than the land. The air in contact with the land becomes heated like the air in contact with a hot light bulb

or the air above a stove. It becomes lighter and rises as the cool air over the water moves in under the heated air to displace it. This cool air is the sea breeze.

Air is heated and cooled by contact with the earth's surface. Whenever two adjoining areas of the earth's surface have different temperatures, the air above them will have different temperatures. Whenever there are differences in the temperature of air, a wind will be born. Watch the whirling of leaves, dust, or small pieces of paper and you will see a tiny, small-scale wind. Of course not every breeze produces important weather changes, but prevailing winds are of great importance. These winds are also caused partly by the unequal heating of the earth's surface and partly by the rotation of the earth.



101 *Sea breezes and land breezes near the coast are caused by differences in temperature. By day the land is hot and the water cool. By night the water is still cool but the land is cooler.*

THE PREVAILING WINDS OF THE EARTH

You will probably remember from your study of geography that winds that blow day after day are called "prevailing winds." They blow over large parts of the earth. Some of these big winds are called "trade winds," for the traders of ancient times sailed the seas in the paths of these winds. Look at Fig. 102. It will help you to recall the names and locations of the prevailing winds of the earth. Which of these winds blow in the area in which you live?

The names of the prevailing winds indicate the direction from which they are blowing. Thus the westerlies come from the west, the northeast trade winds from the northeast, and so on. How do these winds arise?

Wherever the rays of the sun strike the earth nearly vertically, the earth becomes very hot. This happens at the equator and in the areas on either side of it, called the torrid zone. The air next to the earth is heated and rises.

In the Arctic and Antarctic regions, there are long periods when the sun does not shine at all. These regions are very cold. The air above them is chilled and sinks as it spreads out away from the North and South Poles. Thus a circulation of air begins—hot equatorial air rising and moving toward the poles while cold polar air masses are moving toward the equator close to the earth's surface. This circulation, you will see, gives us only two prevailing winds, one from the North Pole, a north wind; one from the South Pole, a south wind.

The spinning of the earth also affects the motion of the air. The earth rotates from west to east. This spinning

causes winds in the Northern Hemisphere to be twisted to the right and winds in the Southern Hemisphere to be twisted to the left. The result of this action of the earth's spinning motion on winds is shown in Fig. 102.

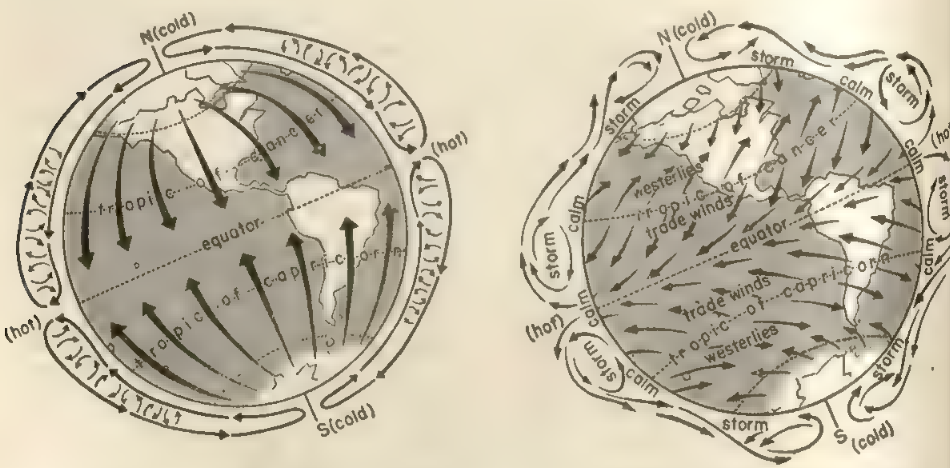
HORSE LATITUDES AND DOLDRUMS

But this is not the whole story. There is a lot of territory between the poles and the equator. Thus we find that the rising hot air of the equator has cooled considerably by the time it has reached the vicinity of the Tropic of Cancer to the north and the Tropic of Capricorn to the south. The Tropic of Cancer is at 23.5 degrees north latitude. The Tropic of Capricorn is at 23.5 degrees south latitude (Fig. 102). As the rising hot air begins to cool in the region north of the Tropic of Cancer and south of the Tropic of Capricorn, it begins to flow earthward. But by this time its temperature is not much different from the temperature of the air over the land beneath it. Thus at these points on the earth's surface (Fig. 102), there are areas of calms comparatively free of wind; that is, there is little northward or southward flow of air across the earth's surface.

In the days of sailing ships, the seas near the Tropic of Cancer were known as the "horse latitudes," a belt of calms. The legend is that the ships which often carried horses frequently were caught and delayed in this belt of calms. In order to save their limited supply of drinking water for themselves, the sailors were sometimes forced to throw the animals overboard. There is, of course, a similar calm area around the Tropic of Capricorn. There is another calm area surrounding the equator, where over a belt many miles wide the air is rising. Within this belt there is very little sideways motion of air. This area of calm over the equator is called the *doldrums* (dŏl′drŭmz).

ALTITUDE CHANGES THE WEATHER

Unequal heating of the earth's surface and the spinning of the earth are not the only things that cause the



102 *These diagrams show how the prevailing winds of the earth are produced. What are the prevailing winds of the United States?*

movement of air. Altitude also has an effect upon the motion of air.

First, you ought to know that the temperature decreases as the altitude increases. The first five to seven miles of the atmosphere above the surface of the earth at sea level are known as the *troposphere* (trŏp′ō sfēr). Within the troposphere the main weather changes occur. There the temperature of the air drops, on the average, one degree Fahrenheit every 300 feet. About seven miles up, a constant temperature of about −67 degrees Fahrenheit is reached.

Sometimes cold air sinks and may then collect in valleys. This causes the temperature in the valleys to be lower than on nearby hilltops. Sometimes this change of temperature ruins the farm crops in the valley. Cold air collected over low places also makes snow last longer in those places.

Decrease in the temperature with increase in altitude has been discovered as far up into the troposphere as man has explored. Differences in temperature which occur at various altitudes have led some scientists to compare the earth's atmosphere to an onion made up of layers (Fig. 55). The lowest layer is the troposphere. Above that, there is a thin layer called the *tropopause* (trŏp′ō pôz) in which there are no temperature changes (Fig. 55).

The next layer is the *stratosphere* (străt′ō sfēr). Reports obtained from sounding balloons and from instruments sent into the stratosphere by rockets indicate that in this region the temperature may increase gradually. At a height of 25 miles, it is thought to be about 170 degrees Fahrenheit. At a height of 50 miles, the temperature again drops to zero. Here the stratosphere ends and a layer called the *ionosphere* (ī ŏn′ō sfēr) begins. The nature of the ionosphere is one of the major mysteries of science. We shall find out more about weather conditions at high altitudes as rockets go higher into the ionosphere.

AIR PRESSURE

You have seen how differences in temperature of the earth produce movements of the air known as winds. You have also seen how altitude has an effect on the temperature. Differences in altitudes also account for changes in air pressure (Fig. 103).

THE CHANGING AIR PRESSURE

You know that air has weight. For instance, the air in an ordinary classroom may weigh from one-quarter to one-half a ton. Because air has weight, it can exert pressure.

There are constant slight changes in air pressure in any one area at sea level. When we speak of an air pressure of 14.7 pounds per square inch, we really are speaking of the average air pressure. Air pressure at any particular place may go slightly above 14.7 pounds per square inch or slightly below this amount. Furthermore, air pressure decreases as we go into the upper air. What causes these changes? What effects are produced by changes in air pressure? Let's start from the ground up.

WHY AIR PRESSURE CHANGES

It will help us to understand changes in pressure if we think of the atmosphere as a kind of seesaw. Suppose four boys sat on a seesaw, two boys of the same weight on one end of it, and two boys of identical weight on the opposite end, with the boys placed at equal distances from the middle. If they sat

still, it is evident that they and the seesaw would be motionless. Suppose one of the boys got off his end of the seesaw, what would happen? Think of the atmosphere as a kind of seesaw in perfect balance with equal numbers of molecules (having the same weight) on opposite ends of the seesaw. That is, there is an equal weight of molecules and, therefore, equal pressure on both sides. This sometimes happens and the air is dead calm. Now suppose something were to remove some of the molecules from one end of the seesaw. The weight on one side is then less than on the other. The lighter end (the one with a lesser weight of molecules) would then go up. The opposite end would go down.

What do you suppose could lighten one end of an atmospheric seesaw? Let's remember the trip we took to the shore where the air rose over the warm areas on the land and sank over the cooler areas of the ocean. This unequal heating of the air is one of the causes of change in air pressure (and in our atmospheric seesaw). Cold air is heavier and moves in to displace the warm air that rises. Cold air, therefore, has a higher pressure than warm air. Another, although minor, cause of change in air pressure is the increase in water vapor in air. For the present it is enough to say that a given volume of dry air at a given temperature has a higher pressure (weighs more) than does an equal volume of air containing some water vapor at the same temperature. In the next chapter you will learn more about changes in air pressure as you learn ways of measuring this pressure. To demonstrate the power of air pressure, pump some of the air out of a large discarded oil can. Why will this cause the can to collapse?

WATER VAPOR IN THE AIR

Generally, when people think of weather they do not think of pressure changes or the movement of the atmosphere. They think of temperature changes and of humidity, rain, snow, sleet, or fair weather.

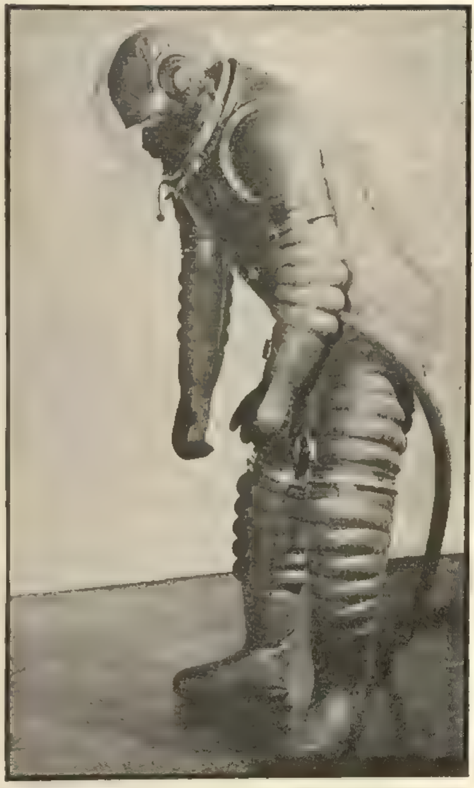
WATER VAPOR AND CHANGES IN WEATHER

Water has a great capacity for holding heat. Water takes a long time to warm up. Therefore oceans and large lakes have an important effect on the weather. Cold air blowing across large bodies of water in winter is warmed somewhat by the heat still in the water. Hot air in the summer is cooled by giving up its heat to the cooler water. Winters along the seacoast are less cold than those in inland areas because the water holds a good deal of the sun's heat acquired in the summer. On the other hand, as compared with inland areas, summer temperatures at the seacoast are lower. However, discomfort may be as great or greater near the seacoast in both summer and winter because of the greater amount of water vapor held by the air.

Water vapor in the air affects each one of us whether or not we live near large bodies of water. Perhaps you have heard the remark, "It isn't the heat, it's the humidity." What does this mean?

HUMIDITY

You have noticed the dampness of the air when it is foggy or when it rains or snows, hails or sleets. But there is some moisture in the air at all times and at all places in the form of invisible water vapor. From 0.1 per cent to 2.5 per cent of the volume of air may be water vapor. Water vapor is a gas.



103 *The deep-sea diver on the left and the aviator on the right are wearing suits which enable them to withstand unusual pressures. Which one works under greater than normal air pressure? Why has each a hose attached to his suit?* (*U.S. Navy and U.S. Air Force*)

The higher the temperature of the air, the more moisture it can hold. The lower the temperature of the air, the less moisture it will hold. Thus when the temperature of the air drops suddenly some of the moisture in it may condense as clouds or fall as rain.

The amount of moisture in the air is called the *humidity*. High humidity may make you uncomfortable. This is partly because your body is constantly giving off water. The heat of the body normally turns this water into vapor. The water is said to evaporate into the air. However, if the humidity is high, that is, if the air already contains a good deal of water, the water from your body cannot evaporate easily. As a result, you may feel sticky and warm. Instead of evaporating into the air, your body water stays on your body and forms sweat.

THE WATER CYCLE

Water, like air and all other substances, is composed of molecules, and these molecules are always in motion. They move fastest when they are heated. Those that move fastest leave the surface of the water and enter the air to form water vapor. This is the process of evaporation noted above. On very hot dry days evaporation is fast; on very cold or humid days it is

slower. Evaporation goes on at night as well as by day.

Heat is required to change water into water vapor. For example, wet your hand with water and then notice how cool your hand will feel as the water evaporates. The evaporation of the water removes heat from your hand; to put it another way, the heat of your hand helps cause the water to evaporate. The effect of evaporation also accounts for the shivering you do when you stand around in a wet bathing suit on a breezy day. Some of your body heat is lost as the water molecules evaporate into water vapor.

CLOUDS

Although the water in the air is generally invisible, it sometimes condenses into droplets which can be seen. For example, water vapor may condense to form clouds or fog. This generally happens when the air temperature falls because as air cools it cannot hold so much water.

The formation of clouds is easy enough to understand. Just breathe out on a cold day. The cold air outside your body cannot hold as much water vapor as the warm air inside your body. The small cloud that forms from your breath consists of millions of tiny droplets of water. The fog and clouds you see in nature are formed in much the same way when warm moist air comes in contact with cooler air. When the droplets become large enough they may fall to earth as drops of rain. This is called *precipitation* (prē sĭp'ĭ tā'shŭn). If the air is very cold, some of the rain drops may freeze and form sleet. Hail, another kind of precipitation, is formed from rain clouds in a different way. This is explained in Chapter 9.

You know that temperature decreases with altitude. As the warm air laden with water rises from the earth, it reaches an upper region and is cooled. Its water vapor may then condense to form clouds. Sometimes a cloud is formed at a temperature below the freezing point of water. This is true of the high clouds which form in the upper troposphere where the air is very cold (Fig. 55). Such clouds may consist of supercooled drops of water. Supercooled drops of water are those which do not form ice in spite of the fact that they are at a temperature below 32°F. Under certain conditions, a cloud made up of supercooled water droplets may change quickly into a cloud of snowflakes. Not long ago, Dr. Vincent Schaefer of the General Electric Research Laboratories discovered a way to change a cloud of supercooled water droplets into a snow cloud.

You can duplicate his work simply by setting up the cold chamber shown in Fig. 104. Breathe into it. A cloud will form. Then shave bits of dry ice into the cloud. (Warning: don't hold the dry ice in your bare hand.) You will soon see snow crystals appear. This demonstration was devised by a high school girl after she read an account of Dr. Schaefer's discovery.

Thus, water leaves the earth by evaporation, forms clouds, falls in precipitation as rain, sleet, snow, or hail and evaporates again. This is the water cycle which repeats itself again and again. And the heat which moves water from the earth into the atmosphere is furnished by the sun.

THE SUN'S ENERGY AS A WEATHERMAKER

With the study of the water cycle, you have almost completed the roll call of the weathermakers. We started

out to discover what makes the weather change. First, we learned that differences in air temperature change the weather by creating breezes and winds. We learned that pressure differences also produce weather changes. We have found out that the air temperature and the air pressure change as we go farther above sea level. Then we discovered that humidity, or the amount of water vapor in the air, is also a factor in weather changes. The heat sent out or radiated by the sun and reflected by our earth is another important source of change in the weather.

RADIATION FROM THE SUN CHANGES THE WEATHER

It surely is no news to you that changes of season bring changes in the weather; that is, it is warmer in summer than in winter. In Chapter 10, you will learn why certain weather changes are seasonal. Right now we are interested in the daily weather. No doubt you have noticed that the weather usually changes a bit after nightfall and again at dawn. You may have realized that our weather depends more upon the sun than upon any other single factor, except the atmosphere itself.

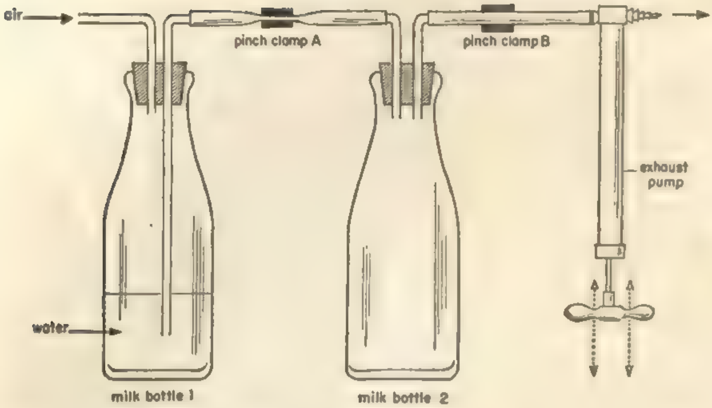
The earth's blanket of air, the atmosphere, is clear enough to permit some radiation from the sun to reach the earth. But the gases and water vapor in the atmosphere also serve to protect us from receiving too much radiation. If we lived on the moon, which has no atmosphere, we would have to wear special suits to obtain this protection. The atmosphere also permits the earth and its oceans to retain some of the sun's heat during the night. By contrast, the temperature of the dark side of the moon is thought to be near absolute zero. A humid, cloudy atmosphere at night holds much of the sun's radiation on earth. Clear, dry, cloudless nights permit more of the earth's heat to be radiated. Thus on clear nights, soon after sundown, the earth's temperature and that of the air next to it fall rapidly.

THE ABC'S OF WEATHER WISDOM

Weather wisdom is not easy to acquire. In this chapter, you have learned

104

Dr. Vincent Schaefer and Kathleen Roan, a high school girl, demonstrate a method of producing snow by seeding a supercooled cloud with grains of dry ice. The cold chamber was made by the girl from two wash boilers with ice and salt between them and insulation on the outside. (*General Electric*)



105
This diagram illustrates an experiment with normal and reduced air pressure. Is the water pushed or pulled from bottle 1 to bottle 2?

that the sun, the motion of the atmosphere, the water cycle, altitude, radiation from the sun, condensation, evaporation, the motions of the earth, and the make-up of the atmosphere are all responsible for changes in the weather.

To be able to predict what kind of weather is coming next, you need to know facts and figures. For instance, you need to know how much water vapor there is in the air. You need to know just how fast the wind is blowing. You need to know not only how high the clouds are but what kind of clouds there are. In the next chapter, you will discover how to obtain this information.

GOING FURTHER

1 *Effect of pressures.* Set up the apparatus shown in Fig. 105. Close clamp A, open clamp B. Pump some of the air out of milk bottle 2. Close clamp B and open clamp A. What made the water flow out of milk bottle 1? In which milk bottle was the air pressure higher? In which was it lower? In which direction will air flow when air pressure changes? Try this with a milk bottle full of smoke instead of water.

2 *Heat and pressure.* Does the heating of the air produce pressure changes? Drop a piece of burning paper into a milk bottle. Place the palm of your hand over the mouth of the bottle the instant the flame goes out. Wait a full minute. Now raise your hand. Explain the result.

3 *Words are ideas.* Can you use these words in a sentence which will give their meaning? Use the glossary.

condensation	humidity	meteorology
doldrums	ionosphere	precipitation
evaporation	land breeze	radiation
horse latitudes	stratosphere	trade winds
troposphere	water cycle	sea breeze

4 *Put on your thinking cap.*

1. Why is so much more known about the troposphere than about the stratosphere?

2. Some scientists have compared the atmosphere to an onion because both are composed of several layers. What are the main characteristics of the various layers of the atmosphere?

3. Why may the atmosphere also be described as a transparent blanket? Compare the blanketing effects of the atmosphere with the effects produced by the blankets on your bed before and after you are in the bed.

4. Why is our sun also called the star that makes our weather?

5 *Test yourself.* In your notebook, complete the following sentences with a correct word or phrase. Do not mark this book.

1. We are always surrounded by ......, which is always in motion.

2. One major cause of winds is the unequal ...... of the atmosphere. The other major cause of winds is the ...... of the earth.

3. Air pressure is the ...... of the air on each square inch of the earth's surface. At sea level, the pressure is about ...... pounds per square inch.

4. In a cupful of warm air, there are ...... molecules than there are in a cupful of cold air.

5. The molecules of warm air move ...... than the molecules of cold air.

6. As you travel upward toward the tropopause, the ...... and the ...... of the air become less than at sea level.

7. The main changes of weather occur in the ...... portion of the atmosphere.

8. Humidity means the amount of ...... in the air. When the humidity of the air is ......, evaporation occurs more slowly.

9. The atmosphere and the clouds shield us from too much ....

10. The amount of heat lost by the earth through radiation is greatest on nights that are ....

6 *Adding to your library.*

1. Buy Weather Bureau publication 1445, a "Weather Glossary." Read it as a reference book or encyclopedia. Write to Superintendent of Documents, Washington, D.C., for information about it.

2. For the student with a good reading vocabulary, *The Weather* by George Kimble and Raymond Bush (a Pelican Mentor Book, 35 cents) is recommended. It has good descriptions of seasonal weather.

3. "Meteorology" and "The Air Ocean" are available in both chart and booklet form. They are publications of the Air-Age Education Research and are good references.

CHAPTER 9

PREDICTING WEATHER CHANGES

The one thing almost everybody tries to do is predict what tomorrow's weather will be. Some people get no further than to say, "I think it will be a nice day tomorrow, if it doesn't rain." They are the kind of people who rely upon a weather almanac that gives predictions for an entire year ahead. Or else they are forever quoting some proverb based on a superstition handed down from the Dark Ages. They take the ground-hog day superstition seriously.

AMATEUR WEATHERMAN

On the other hand, there are the co-operative observers who have formed an organization called the Amateur Weathermen of America. These co-operative observers are persons of all ages who make their own weather observations and report them to the

106 *These scientists of the United States Weather Bureau work under rugged conditions on the top of Mount Washington in New Hampshire to obtain data needed for accurate weather forecasts. (U.S. Weather Bureau)*

United States Weather Bureau. They have to know what they are doing and why they are doing it. If you want to be a co-operative observer or an amateur weatherman, this chapter will give you the know-how you need to start.

THE WEATHER BUREAU

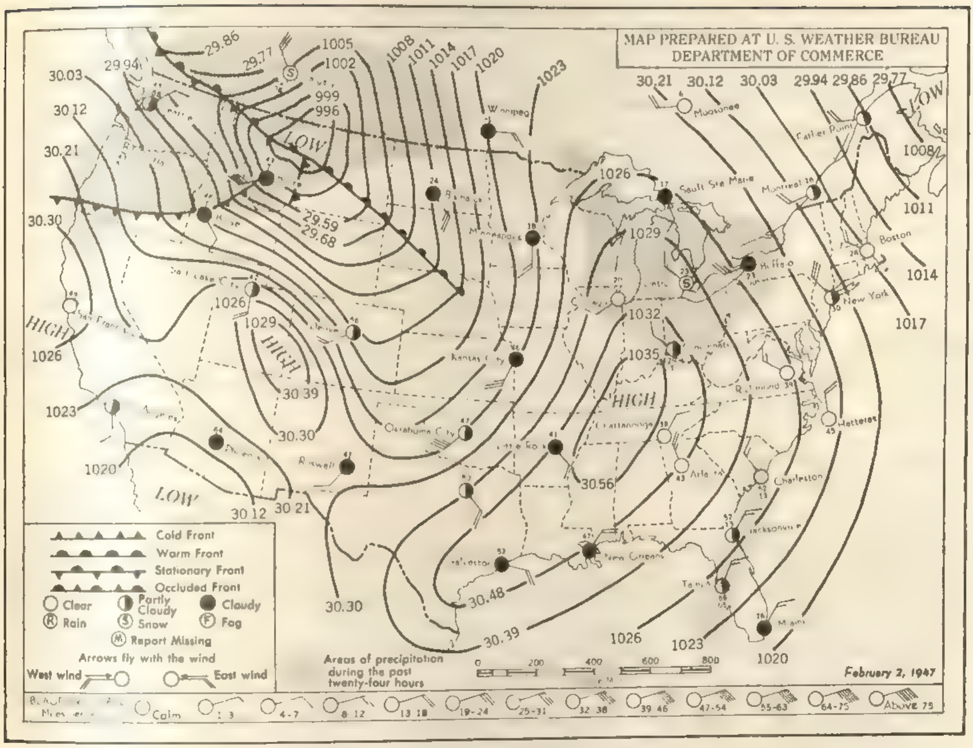
The secret of success in predicting weather is co-operation. Weather predictions like those our Weather Bureau makes are correct 80 to 90 per cent of the time. Its predictions are based on the reports of hundreds of observers scattered over the widest possible area, including outposts in Canada, Alaska, Greenland, and other remote regions (Fig. 106).

In 1890, the Congress of the United States passed an act establishing the Weather Bureau. At first the Weather Bureau was under the Department of Agriculture. Since 1940, it has been in the Department of Commerce.

WHAT A WEATHERMAN NEEDS TO KNOW

Whether amateur or professional, a weatherman needs to know certain facts before he makes a prediction. For example, he wants to know the following:

The temperature of the air
The pressure of the air
The relative humidity
The speed of the wind
The direction of the wind



107 *This weather map may be read with the help of the key in the lower left-hand corner. What kind of weather is there near Detroit, Michigan? Name two cities where it was cloudy and two where it was clear or partly cloudy.* (*U.S. Weather Bureau*)

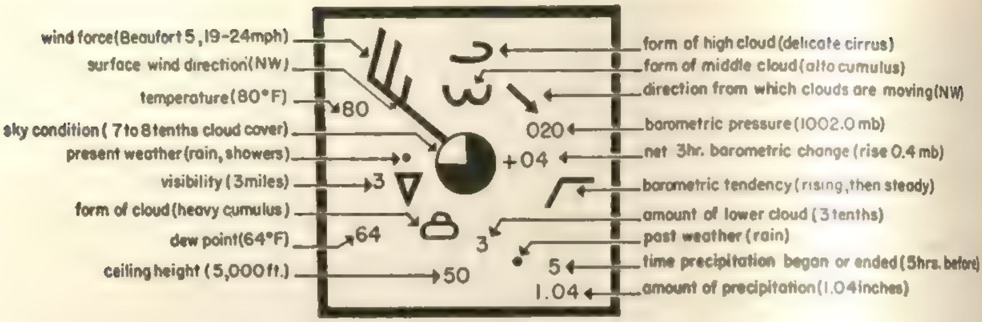
The kind of clouds and their height
The direction the clouds are moving

He also wants to know the location of the high and low air pressure areas, of warm and cold air masses, and a number of other things which will be discussed later.

The weatherman can obtain certain information for his own locality by reading his instruments. However, if he wants to know these facts about other places throughout the country, he must turn to the daily weather map. Weather maps are posted in some public buildings; they are printed in many newspapers; they are mailed to persons who are willing to pay a cent a day. The maps contain the information listed above (and more) for 170 weather stations located in every part of the United States (Figs. 107 and 108). Before you try to read information from a weather map, you should know how the information is obtained; that is, how weather-measuring instruments work and how they are read.

MEASURING AIR PRESSURE AND TEMPERATURE

A thermometer is usually a glass tube with a bulb at one end filled with a liquid such as mercury or alcohol. As the temperature changes, the length of the column of liquid in the tube rises or falls. You read the temperature



108 *On larger weather maps the data reported by more than 150 stations are shown in symbols and numbers like those in the box.* (*U.S. Weather Bureau*)

in degrees from a scale marked on the tube or alongside it.

THE VARIOUS THERMOMETERS

Weather experts do not measure the temperature of the air with an ordinary household or laboratory thermometer which tells you only the temperature at the moment. They want to know the highest and lowest temperature in their locality over a twenty-four hour period. To get this information, weather experts use either a *maximum-minimum thermometer* or a *thermograph*. A maximum-minimum thermometer is made so that a tiny metal marker is left at the lowest temperature in a given period. Another marker is left at the highest temperature registered during this time. Of course, the temperature at any time can be read in the same way as from an ordinary thermometer by noticing the height of the liquid in the tubes.

A thermograph is even more informative than a maximum-minimum thermometer, for it provides you with a complete record of every change of temperature that has occurred. As the name suggests, the record is in the form of a line drawn by an automatically controlled tracer on a piece of graph paper. The graph paper is attached to a revolving drum turned by a clock.

In either case, the temperature of the air is measured in degrees Fahrenheit. Daniel Gabriel Fahrenheit (1686–1736) was the first to use this scale for measuring air temperature. He was also the first to use mercury in a thermometer. On the Fahrenheit scale 32° is the freezing point of pure water and 212° is the boiling point of pure water at sea level. The little circle ° is an abbreviation for the word "degrees." Just the letter "F." is used to indicate Fahrenheit—thus 212° F. You may also have seen a centigrade thermometer. On the centigrade scale, 0° is the freezing point of water and 100° is the boiling point at sea level.

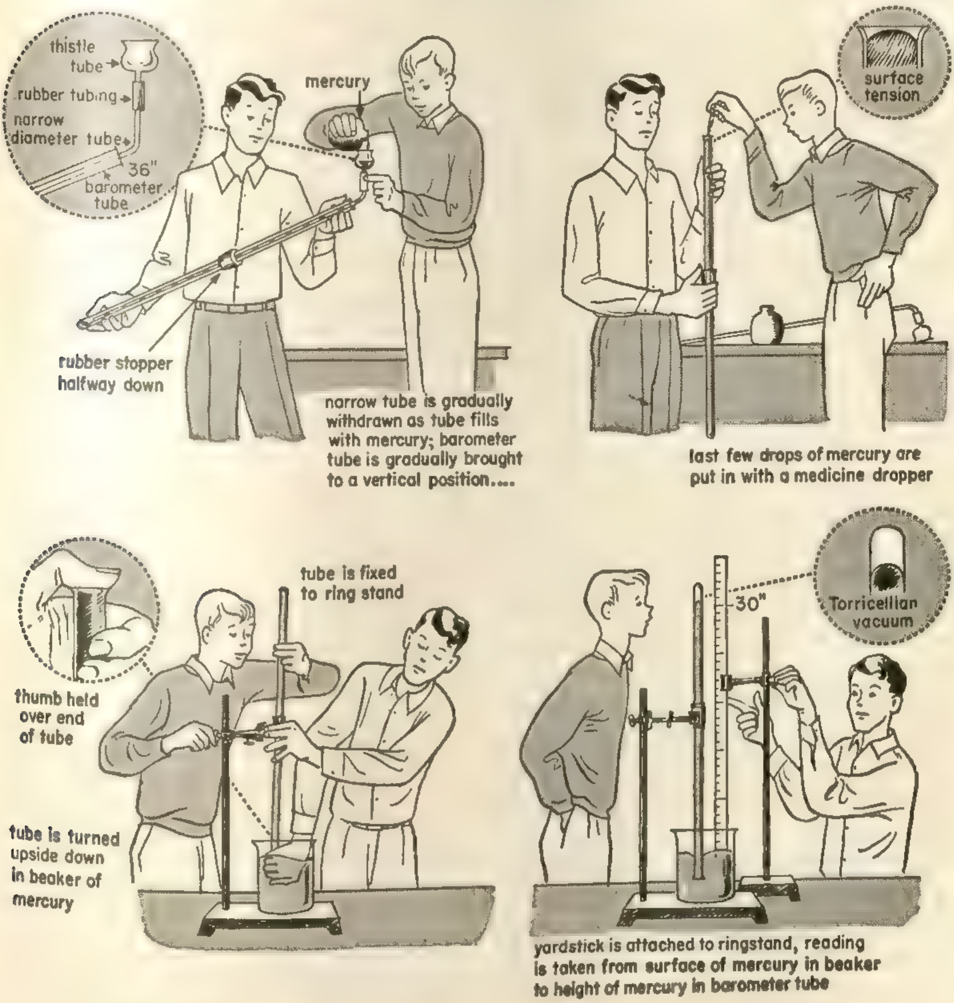
WATER AND MERCURY BAROMETERS

Air pressure is sometimes called the *barometric* (băr′ō mĕt′rĭk) pressure because air pressure is measured by means of a barometer (bȧ rŏm′ē tẽr) or a *barograph* (băr′ō grăf). When the air pressure decreases, the column of mercury falls, for it is air pressure that holds the mercury up in the tube. Mercury barometers are expensive and so you may have to be content with making a crude mercury barometer like the one invented in 1643 by Evangelista Torricelli (tôr′rē chĕl′lē, 1608–1647), a pupil of Galileo.

Torricelli discovered that the pressure of air at sea level is able to hold up a column of mercury about 30 inches high. Mercury weighs 13.6 times more than water so you see why water is not used in barometers. If you used water, you would have to use a tube about 34 feet in height. Otto von Guericke (gā′rĭ kĕ, 1602–1686), the famous Mayor of Magdeburg, actually constructed a water barometer but the superstitious townspeople made him take it down. They noticed that every time the water level went down it rained or there was a storm. Unthinkingly, they blamed the bad weather on the barometer.

Why don't you make a mercury barometer? Fig. 109 shows you how to do it.

109 *A mercury barometer may be made by following the four steps shown here. Why must the mercury be poured carefully? What is the purpose of the rubber stopper?* Caution: *Do not put your hand into the mercury if you have any cut on your skin. Scrub your hands before eating. Mercury is a dangerous poison inside your body.*



OTHER BAROMETERS

There are other kinds of barometers. One type, containing no liquid, is called an *aneroid* (ăn′ẽr oid) barometer. An aneroid barometer uses a small flexible metal box from which most of the air has been removed. It is attached to a pointer which moves around a dial. Since part of the air has been removed from the tin box, the pressure of air in it is less than the outer pressure of 14.7 pounds per square inch. The box, therefore, is pressed in to a certain extent by the air pressure outside it. If the outer air pressure is lowered, there is less pressure on the aneroid box. The box expands, therefore, and the expansion forces the needle to move on the dial. If the outer air pressure increases, the box is pushed in and the needle also registers this (Fig. 110).

The aneroid makes it possible to do away with the three foot tube of a liquid barometer (the Torricelli barometer) and also eliminates a great deal of weight as well as the danger of spilling the mercury. An aneroid is also useful for measuring altitude. When so used, it is called an *altimeter* (ăl tĭm′-ē tẽr, see Fig. 110).

You recall that as we go up in the atmosphere the pressure decreases. If we were to carry a mercury barometer with us, we would find that the mercury level would drop about one-tenth of an inch for every 90 feet in height. Thus a barometer can also be used as an altimeter, that is, to tell us how high above sea level we are. But a mercury barometer is inconvenient to use in an airplane; therefore, an aneroid is used.

A *barograph* is merely an aneroid barometer connected to a tracer which draws a continuous record of pressure changes. These changes are recorded on a piece of graph paper revolving on a drum controlled by a clock (Fig. 110).

NORMAL AIR PRESSURE

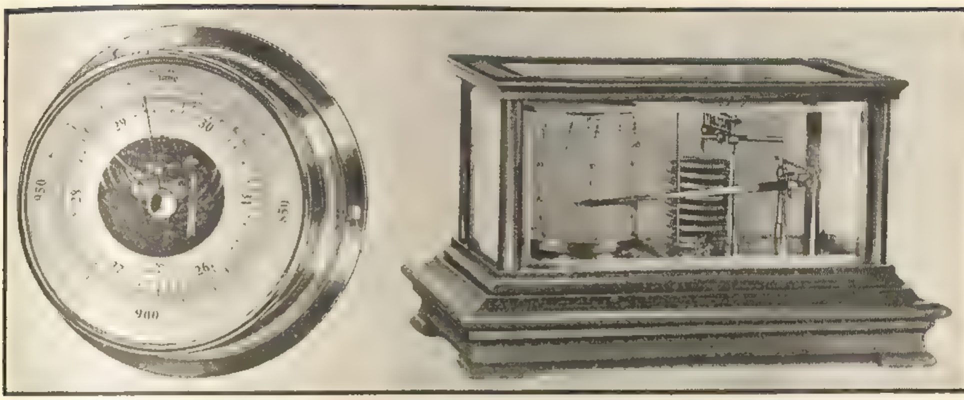
Normal air pressure (at sea level) may be described or measured in a number of ways as follows:

29.92 inches of mercury
76 cm. of mercury [1]
760 mm. of mercury [2]
33.9 feet of water
1 atmosphere
14.7 pounds per square inch
1013.25 millibars

All these figures mean the same thing; they measure the normal pressure of air on one square inch of the earth's surface at sea level. The description of air pressure preferred nowadays by the weather experts is expressed in millibars. On a barometer scale .1 of an inch measures the same air pressure as about 3.4 millibars. You do not need to worry too much about the arithmetic of changing barometric pressure into millibars. Every weather map gives the comparison of inches of mercury and millibars somewhat as it is shown on the scale [3] printed here:

Inches	*Millibars*
29.0	982.05
29.1	985.44
29.2	988.83
29.3	992.21
29.4	995.60
29.5	998.99
29.6	1002.37
29.7	1005.76
29.8	1009.14
29.9	1012.53
30.0	1015.92
30.1	1019.30
30.2	1022.69
30.3	1026.08
30.4	1029.46
30.5	1032.85

[1] 1 inch = 2.54 centimeters (cm.)
[2] 1 cm. = 10 millimeters (mm.)
[3] Based on 1″ mercury at 32° F. = 33.8639 millibars



110 *An aneroid* (left) *and a barograph* (right) *are used to measure changes in atmospheric pressure. The numbers on the outer scale of the aneroid are millibars. Which numbers indicate the pressure in inches of mercury?* (*Taylor Instrument Co.*)

It may surprise you to learn that the barometer changes very slightly in any one place. Over a period of 66 years, the Weather Bureau in Philadelphia recorded a total change of only 2.48 inches between its record high of 31.02 inches and its record low of 28.54 inches. A drop of even one inch in a period of 24 hours is unusual and marks the rapid approach of a violent storm.

THE FALLING BAROMETER

Have you heard the statement: "The barometer is falling; a storm is on the way"? When a barometer falls, the level of the mercury goes down. This means that the air pressure in the area being observed is dropping. Such an area is called a "low pressure area," or simply a "low." You should know that a major cause of lowered pressure in the atmosphere is an increase in temperature (see p. 146).

You should also know that the presence of a high percentage of water vapor in the air is a cause for a lowering of air pressure, although the decrease in air pressure due to the presence of water vapor is slight.

If you were to weigh a box of air, you would find it has a certain weight. If you were to fill the same box with water vapor, under the same conditions, you would find that the box of water vapor now weighs less than the box of air. Water vapor should not be confused with visible droplets of moisture in the air. Water vapor is a gas which cannot be seen, while visible moisture is a cloud consisting of tiny droplets of water. Now when water vapor is introduced into a volume of air, it displaces the molecules of gases composing the air. The resulting volume of water and air weighs less. This is so because the molecules of water vapor weigh less than an equal number of molecules of the normal mixture of gases found in dry air. Since the molecules of water vapor replace some of the molecules of the other gases, the more water vapor there is in the air, the less the air weighs.

A barometer placed in warm air containing much water vapor falls since this kind of air does not exert as much pressure as does colder and drier air. Since water vapor in air may fall as rain, a falling barometer may mean

that rain is coming. This does not always occur for the temperature must drop low enough to cause the water molecules to condense as rain drops. On the other hand, a high barometer, which means high pressure, is generally interpreted as dry or fair weather.

111 *This is one type of rain gage used by the United States Weather Bureau. It is connected to an electrically operated recorder. Each time .01 inch of rain collects in the bucket inside, it tips and thus closes a circuit for an instant. How many times does the bucket tip when .1 inch or 1 inch of rain falls?* (*U.S. Weather Bureau*)

MEASURING PRECIPITATION

Co-operative weather observers may report to the Weather Bureau on changes of air pressure if they wish but they must record temperature changes and precipitation. As you remember, precipitation means any form of moisture that falls from the air to the earth. Rain, snow, and hail are forms of precipitation. Dew is not precipitation because it does not form in the air and fall to the ground. Dew forms upon objects on or near the ground. The Weather Bureau supplies co-operative weather observers with a thermometer for measuring the air temperature. It also supplies a rain gage with which precipitation can be measured. Many amateur weathermen buy their own instruments and gages. Fig. 111 shows one type of gage for measuring rainfall.

MEASURING RAINFALL

In the United States, rainfall and snow are measured in inches. The average yearly precipitation for Washington, D.C. is 42.16 inches. A day during which .01 inches or more rain falls is considered a rainy day. Most people do not need a rain gage to assure them that a particular day is rainy. However, a record of the rainfall during a season may be very important in warning of floods to come. It shows the amounts of water that will be available for wells, reservoirs, and agriculture, and when to take precautions against the effects of a drought. What is the yearly precipitation in your area?

A rain gage should be set up in a place where average conditions of precipitation prevail. If it is placed too close to a wall, it may not receive the full amount of rain that actually falls

in open places. In the smaller rain gages, a ruler is inserted and the reading taken at the top of the wet portion just as you might read the level of the oil in the engine of your car. Snow is collected and measured in a similar way after it has melted.

If you are using a rain gage, read it as soon as the rain stops or else some of the water collected in the gage may evaporate.

MEASURING RELATIVE HUMIDITY

It is one thing to measure the precipitation and another to measure *relative humidity.* The relative humidity is a measure of the amount of water vapor in the air compared to the amount the air can hold at that temperature.

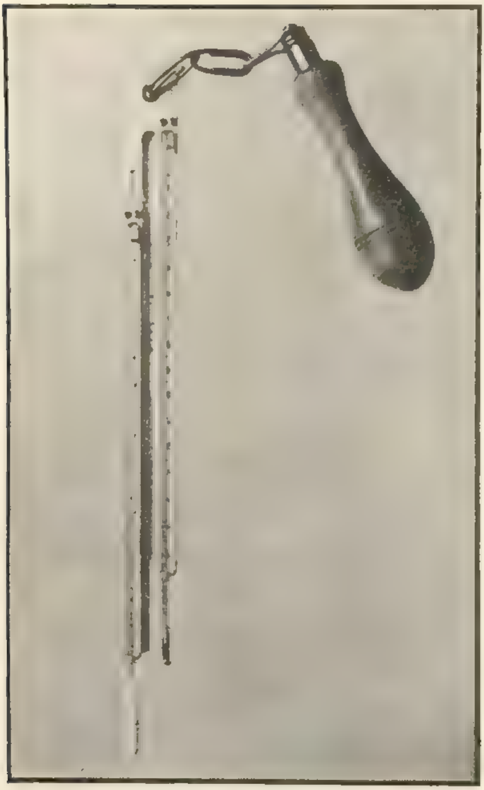
Relative humidity is always measured in percentage. A relative humidity of 50 per cent means that the air is holding just half as much water vapor as it can hold if the temperature remains the same. What do you suppose will happen to air with a relative humidity of 100 per cent if the temperature should drop a little? It will rain, or dew will form. You can demonstrate this action easily by filling a metal cup with ice. As the ice lowers the temperature of the cup, the cup in turn lowers the temperature of the air around it. With this lower temperature, the air cannot hold so much water vapor. The air next to the cup is now saturated with water vapor and it therefore has a relative humidity of 100 per cent. Cooling the air still further causes some of the water vapor in it to condense as water on the side of the cup.

Everyone has seen dew on grass, stones, boards, and other objects on the ground. Dew is formed when warm air, containing water vapor, is in contact with the cool earth. What happens resembles the condensation of drops of water on the side of the ice-filled cup in the experiment above. Why doesn't dew form during the day? During the day, the earth is usually as warm as the air or warmer. Therefore, the temperature of the air is not lowered by contact with the earth and the air continues to hold its water vapor.

You can use a simple but very rough method to determine the presence of water vapor in the air. Water vapor changes the color of a chemical known as cobalt chloride. Cobalt chloride is blue when it is dry; it turns pink or red when it has absorbed moisture from the air. If you will soak some white blotting paper in a strong solution of cobalt chloride and then dry the paper in an oven until the color turns blue, you will have made a good water vapor indicator. Hang the blotter up and watch it turn pink or red as the blotter absorbs moisture from the air. You may want to time the speed at which the paper turns color on days when the humidity is low and on other days when it is high.

MAKING A WEATHER INSTRUMENT

One instrument used to measure humidity is called a *psychrometer* (sī-krŏm′ē tẽr, Fig. 112). If you haven't one, you can make one easily enough. A psychrometer consists of two identical thermometers and a chart such as is shown in Table IV. The chart can be used with any psychrometer. All you have to do is attach a piece of cotton to the bulb of one of the thermometers and moisten it with water (Fig. 112). Then you fan the wet bulb thermometer until the level of the liquid in it stops dropping. Read the temperatures on both thermometers and consult the table. Look down the column in the table giving the dry bulb temperature you have read. Put a ruler



112 *A sling psychrometer is so named because you sling it around to evaporate the moisture from the cotton on the wet bulb thermometer. Why is the wet bulb temperature always less than the dry bulb reading? (U.S. Weather Bureau)*

on it. Then look across the line giving the temperature of the wet bulb thermometer. The number in the box where the column and the line meet is the per cent of relative humidity. An example is worked out for you in Table IV.

MEASURING WINDS

With the exception of the rain gage, the instruments we have studied so far are delicate ones designed for use under protecting boxes or indoors. The measurement of wind direction and speed requires more rugged equipment, like the weather vane. It is not unusual for an amateur weatherman to discover that his weather vane and other instruments have gone with the wind if they haven't been made well and properly guy-wired when attached to the roof.

MEASURING WIND DIRECTION

A weather vane is so familiar an object on the tops of steeples that it does not need to be described here. You have probably seen dozens of them turning in the wind. One question about weather vanes is enough to ask of anyone—which way does a weather vane point? Here is a hint—flags, smoke, and clouds blow in the opposite direction from the source of the wind. Similarly, the heavy end of the weather vane moves away from the source of the wind and the light end of the pointer shoots into the wind or toward the direction from which the wind is blowing. That is the way we name winds too—according to the direction *from* which they blow. A north wind is one that blows *from* the north. Be careful though when you look at a weather map. The arrows that show wind direction (called Beaufort arrows) on a weather map fly *with* the wind, with only the tail feathers showing (Fig. 107).

Beaufort arrows are peculiar things having almost no resemblance to real arrows. On page 167 you see a whole column of them. Each consists of a circle and a line. Attached to the line are other lines, some long, some short. These are the feathers of the arrow but they aren't put there for decoration. Each line and its length indicates a different wind speed. The arrows con-

Table IV. HUMIDITY CHART

DRY BULB TEMPERATURE OF

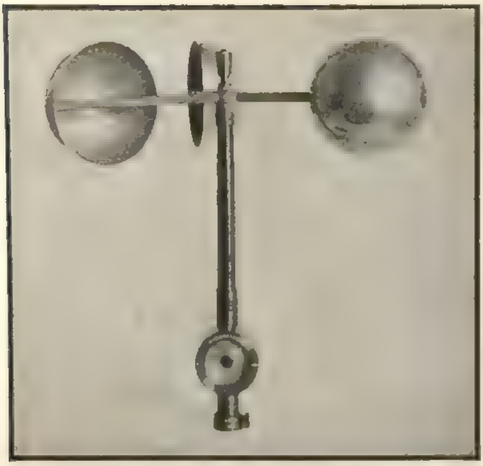
WET BULB TEMPERATURE OF

	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	
41	7	4	2																		41
42	10	8	6	4	2																42
43	14	12	10	7	5	3	2														43
44	18	16	13	11	9	7	5	3	1												44
45	22	20	17	15	12	10	8	6	5	3	1										45
46	27	21	21	18	16	14	12	10	8	6	4	3	1								46
47	31	28	25	22	20	17	15	13	11	9	7	6	4	3	1						47
48	35	32	29	26	24	21	19	16	14	12	10	9	7	5	4	3	1				48
49	40	36	33	30	27	25	22	20	18	15	13	12	10	8	7	5	4	3	1		49
50	44	41	37	34	31	29	26	23	21	19	17	15	13	11	9	8	6	5	4	3	50
51	49	45	42	38	35	32	30	25	24	22	20	18	16	14	12	11	9	8	6	5	51
52	54	50	46	43	39	36	33	31	28	25	23	21	19	17	15	13	12	10	9	7	52
53	58	54	50	47	44	40	37	34	32	29	27	24	22	20	18	16	14	13	11	10	53
54	63	59	55	51	48	44	41	38	35	33	30	28	25	23	21	19	17	16	14	12	54
55	68	64	60	56	52	48	45	42	39	36	33	31	29	26	24	22	20	18	17	15	55
56	73	69	64	60	56	53	49	46	43	40	37	34	32	29	27	25	23	21	19	18	56
57	78	74	69	65	61	57	53	50	47	44	41	38	35	33	30	28	26	24	22	20	57
58	84	79	74	70	66	61	58	54	51	48	45	42	39	36	34	31	29	27	25	23	58
59	89	84	79	74	70	66	62	58	55	51	48	45	42	39	37	34	32	30	28	26	59
60	94	89	84	79	75	71	66	62	59	55	52	49	46	43	40	38	35	33	31	29	60
61	100	94	89	84	80	75	71	67	63	59	56	53	50	47	44	41	39	36	34	32	61
62		100	95	90	85	80	75	71	67	64	60	57	53	50	47	44	42	39	37	35	62
63			100	95	90	85	80	76	72	68	64	61	57	54	51	48	45	43	40	38	63
64				100	95	90	85	80	76	72	68	65	61	58	54	51	48	46	43	41	64
65					100	95	90	85	81	77	72	69	65	61	58	55	52	49	46	44	65
66						100	95	90	85	81	77	73	69	65	62	59	56	53	50	47	66
67							100	95	90	86	81	77	73	69	66	62	59	56	53	50	67
68								100	95	90	86	82	78	74	70	66	63	60	57	54	68
69									100	95	90	86	82	78	74	70	67	63	60	57	69
70										100	95	91	86	82	78	74	71	67	64	61	70
71											100	95	91	86	82	78	74	71	68	64	71
72												100	95	91	86	82	79	75	71	68	72
73													100	95	91	87	83	79	75	72	73
74														100	96	91	87	83	79	75	74
75															100	96	91	87	83	79	75
76																100	96	91	87	83	76
77																	100	96	91	87	77
78																		100	96	91	78
79																			100	96	79
80																				100	80
	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	

WET BULB TEMPERATURE OF

DRY BULB TEMPERATURE OF

Suppose the "dry" thermometer (on your psychrometer) read 72° F., the "wet" thermometer 63° F. Then the relative humidity would be 61 per cent (as above). Check with pages 163 and 164 if you have forgotten how to use this chart.



stitute a weatherman's code for a system of measuring wind speeds invented by Admiral Sir Francis Beaufort during the years 1805–08. He based his scale on the amount of sail a full-rigged frigate of his day could carry at various wind speeds. The modern scale has been based on effects more familiar to those of us who have had no experiences at sea.

THE BEAUFORT SCALE

The complete Beaufort wind scale is shown in Table V.

The speed of the wind is measured by an *anemometer* (ăn′ē mŏm′ē tẽr). There are several forms but the most reliable is designed with three or four cups attached to short horizontal bars. The wind, striking the cups, causes the rotation of the shaft to which the bars are attached. The shaft in turn operates a speedometer (Fig. 113).

OBTAINING UPPER-AIR WEATHER INFORMATION

Important as they are, the measurements of weather conditions that exist near the ground do not provide all the information needed for good weather

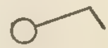
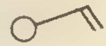
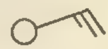
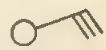
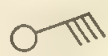
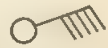
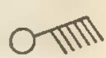
113 (above) *A cup type of anemometer turns, no matter what direction the wind is blowing from. The disk at the bottom is the speedometer, which registers the speed of the wind in miles per hour. (Taylor Instrument Co.)*

114 (below) *Radiosonde balloon and parachute. When the balloon has risen far enough, it bursts. Then the radiosonde (not shown) is lowered by the parachute. Radar (antenna shown at lower right) may be used to track the balloon as it rises. (L. E. Johnson, U.S. Weather Bureau)*

reports and predictions. Weather science has really gone upstairs. Upper-air temperature, upper-air pressure, upper-air humidity, upper-air wind speed and direction, and cloud characteristics are essential for weather prediction.

Temperature, pressure, and humidity are discovered and reported by radio. A light-weight instrument known as a *radiosonde* (rā′dĭ ō sŏnd′) is sent aloft. It is carried by a balloon about three feet in diameter (Fig. 114). Inside is a short-wave radio set which signals back its information obtained by a tiny aneroid barometer, a tiny electric thermometer, and a special psychrometer. The balloon rises until its internal pressure is so much greater than the outside air pressure that it bursts. Then a small parachute opens and lowers the radiosonde gently to the

Table V. THE BEAUFORT WIND SCALE

Beaufort scale number	Weather report description	Miles per hour	Effects of the wind	Beaufort arrow symbol
0	calm	0 – 1	Smoke rises straight up.	
1	light air	2 – 3	Smoke shows wind direction.	
2	slight breeze	4 – 7	Turns weather vane, hairdos are spoiled, leaves begin to whisper, flags flap.	
3	gentle breeze	8 – 12	Flags blow straight out, leaves do nonstop dance.	
4	moderate breeze	13 – 18	Dust clouds rise, hats go to the dry cleaners.	
5	fresh breeze	19 – 24	Small trees bend, rivers and lakes don white caps.	
6	strong breeze	25 – 31	Don't raise your umbrella, telegraph wires hum tunes.	
7	high wind	32 – 38	You have to lean to walk, largest trees in motion.	
8	gale	39 – 46	Branches break off trees, you're glad you're home.	
9	strong gale	47 – 54	Radio aerials collapse, shingles and false cornices are torn off roofs.	
10	whole gale	55 – 63	Trees topple, telephone wire and poles need repair.	
11	storm	64 – 72	It's time to move into the cellar, damage widespread.	
12	hurricane	73 – 82	If you're alive, you are a survivor of a disaster.	

115
This couple is using a theodolite to observe the flight of a pilot balloon (near top of picture). They will learn the direction and speed of the upper air currents. Why is this information important? (U.S. Weather Bureau)

ground. The finder returns it by mail to the Weather Bureau. Sometimes a pilot balloon without a radiosonde attached is sent aloft. Until it becomes lost in the clouds, the balloon's flight is observed through a telescopic range finder called a *theodolite* (thē ŏd′ō līt) to determine wind speed and direction (Fig. 115) or it may be tracked by radar.

CLOUDS AND FRONTS

Weather information is made more accurate by the use of these complicated instruments, but they are not necessary for observing clouds. Very simply, anyone can look up and observe the various clouds that pass, form, and disappear before his eyes. For thousands of years men have watched the changing spectacle of the sky. By watching clouds they have tried to forecast weather. It will be helpful for you to learn to identify the different kinds of clouds—their shape, altitude, speed, and direction. It is much easier than identifying airplanes, a skill so many of you have mastered.

KINDS OF CLOUDS

Clouds can be classified in two ways: by their shape and size, or formation; and by their altitude levels. Actually these two ways are not separate, as you will discover. Clouds of certain types

116 *A few of the many cloud formations. Read from top to bottom: cirrus clouds with their hairlike curls; cirro-stratus clouds stretching across the sky; stratus clouds above, with a fog in the mountain valleys below; cumulo-nimbus clouds, with rain falling in the distance.*

(*U.S. Weather Bureau*)

tend to occur at certain altitudes.

There are four main types of cloud formation. A *stratus* (strā′tŭs) cloud covers an entire sky or a large portion of it with a flat sheetlike layer so that the blue of the sky itself cannot be seen. A *cumulus* (kū′mů lŭs) cloud is shaped like a cauliflower, or like great billows of fluffy wool. A *cirrus* (sĭr′ŭs) cloud (Fig. 116) is commonly known as "mare's tail" or "witch's broom"; it is always white and has the appearance of disordered streaks across the sky. A *nimbus* (nĭm′bŭs) cloud is usually called a "rain cloud" and is dark and heavy in appearance. The names for these formations are, in fact, self-explanatory when you know their original Latin meanings: "stratus" means "in layers"; "cumulus" means "a heap"; "cirrus" means "hairlike curls"; and "nimbus" means "rain."

The *altitude* of clouds must be considered when you undertake to identify clouds. At varying altitudes you will discover combinations of the four main types just discussed. In fact, the names of these types are then linked together. Cirrus clouds usually occur at levels from 20,000 to 40,000 feet. Stratus clouds, on the other hand, occur from the ground level—where they are called *fog* (Fig. 116)—to about 6,000 feet. Now, when the blanketlike stratus clouds are found in very high altitudes they appear to be thin, like cirrus clouds, and they are then called *cirro-*

14

stratus (sĭr'ō strā'tŭs) clouds (Fig. 116). Cirro-stratus clouds are easily recognized because they seem to form a halo about the moon. Or take another combination. When the woolly cumulus clouds appear to extend from the low level of the nimbus (about 1,000 feet where they look dark and heavy) to great heights where they appear silvery white they are called cumulo-nimbus (kū'mū lō nĭm'bŭs) clouds (Fig. 116). These are the familiar "thunderclouds" or "anvil clouds." They appear before a thunderstorm and warn of its approach.

Altogether, there are many kinds of clouds, using combinations like these and others. Not all the names and descriptions can be given here. If you are interested, you can obtain an illustrated book or chart describing these cloud forms by writing to the Weather Bureau in Washington, D.C.

Cloud formations are of the greatest importance to persons making weather predictions. Clouds are the messengers that tell us when changes in the weather are beginning to take place. They supply us with visible evidence of conditions aloft. But the real importance of many cloud types is that they indicate the presence of a cold or warm air *front* and moving air masses.

WEATHER FRONTS AND AIR MASSES

An air mass is a three-dimensional portion of the atmosphere. It has length, width, and height (Fig. 117). Within any moving air mass, the temperature, pressure at sea level, and humidity are everywhere approximately the same. If an air mass lingers in our region for a while, we may have hot, cold, dry, or wet weather depending upon what kind of air mass it is.

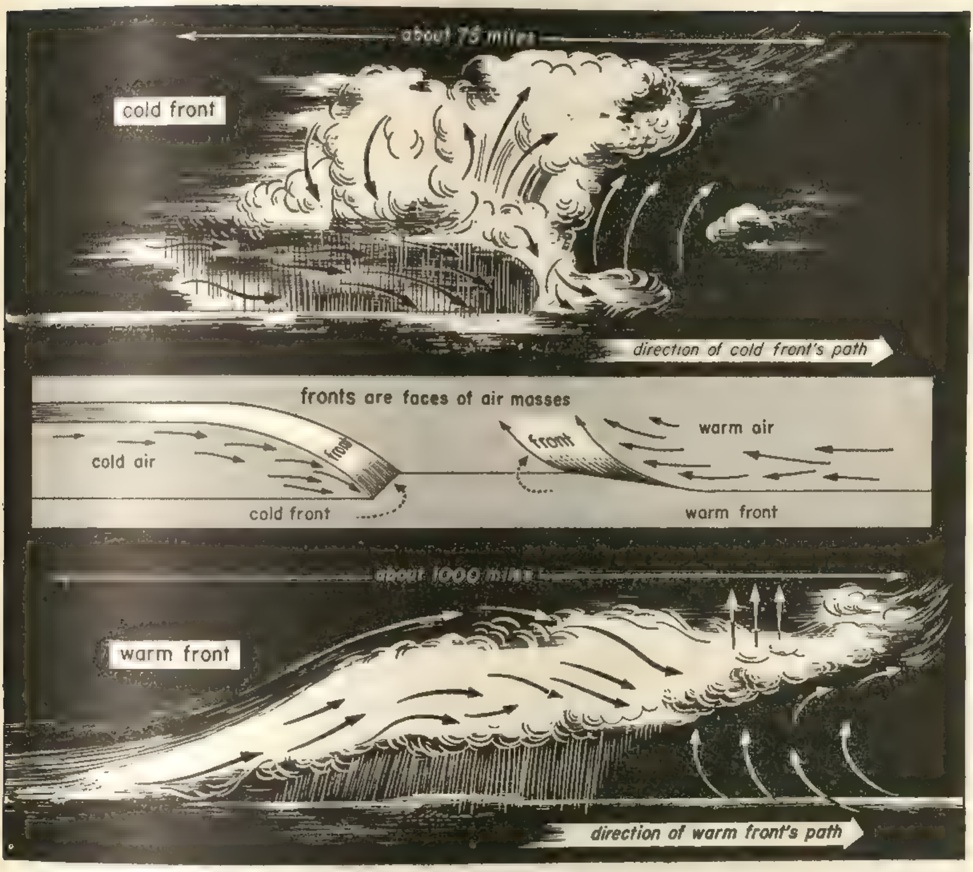
Air masses are named for the regions from which they come. The weather of our country is governed chiefly by air masses of four types: *Polar Continental*, *Polar Maritime*, *Tropical Continental*, and *Tropical Maritime*. Polar air masses come from the frigid zone. Tropical air masses have their source near the equator. Continental applies to an inland origin and Maritime, of course, means air that comes from over the sea. A Polar Continental air mass would mean an air mass which has its origin in the frigid zone, inland. A Polar Maritime air mass has its origin in the frigid zone, over the sea. As you may have guessed, a polar mass is apt to bring us cool weather and a tropical air mass, warm weather.

Whenever one kind of air mass meets a mass of another type, a *front* is formed. The front is the boundary line of the two air masses. The type of front and the type of weather changes that occur along it depend upon the kinds of air masses and how they meet. The two most common types of weather fronts are the warm front and the cold front (Fig. 117).

WEATHER CHANGES ALONG A WARM FRONT

A warm front is the boundary line between two air masses of different temperatures when the warmer air mass is advancing. If the colder air mass were advancing, we would call it a cold front. This boundary or front may extend 1,000 miles or more across the country and be 500 to 600 miles wide. It may slope upward from the ground to a height of about six miles. This is shown in Fig. 117.

The warm front is easily distinguished by the clouds that form along it. As the cool air of one mass mixes with the warmer air of the other, the water vapor in the warmer air condenses to form clouds. At the highest level of the warm front, cirrus clouds



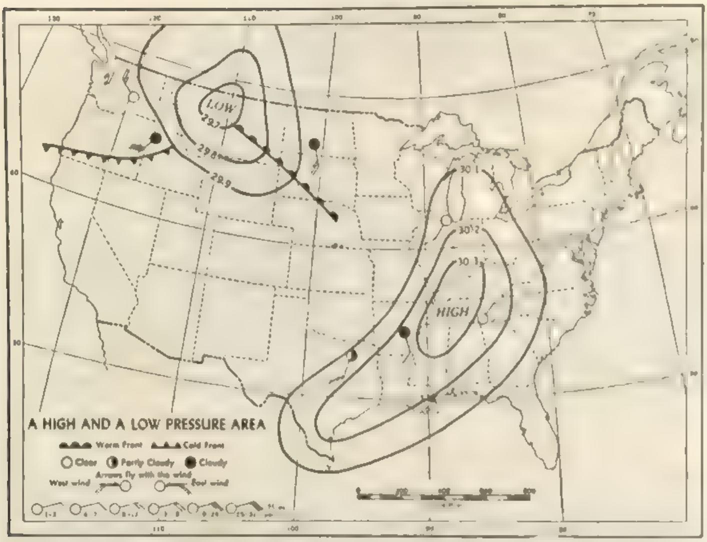
117 *A diagram of a cut through a cold front and a warm front. The middle diagram shows you that air masses have three dimensions with fronts extending across the surface of the earth as well as into the sky.*

form. As the front advances, the level of the cloud ceiling drops and larger clouds appear. Finally come the low level nimbo-stratus clouds from which rain falls.

Other changes accompany the advance of a warm front. The barometer drops and an area of low air pressure called a *cyclone* forms. Winds blow in a large counterclockwise circle (opposite to the direction of the hands of a clock) and spiral slowly in toward the center of the *low* (Fig. 118). When wind speeds range from light (at outer edge) to stronger gale force (near center) and the area covered is 500 to 2000 miles in diameter, we call the cyclone a *storm*.

A tropical cyclone is usually a more violent type of cyclone occurring mainly in tropical zones. It covers a smaller area, seldom as great as 300 miles. This type of cyclone is also called a *typhoon* or *hurricane*. It has no fronts associated with it, at least not in the beginning.

A *tornado* or "twister" is a cyclone covering a still smaller area, sometimes less than a mile in width but having winds estimated to whirl sometimes at



118

Areas of high and low pressure move across the United States in a general direction from west to east. Air flows from areas of high pressure to areas of lower pressure. Will the area of high pressure be moving in the general direction of the Atlantic Ocean or the Rocky Mountains? (U.S. Weather Bureau)

more than 500 miles per hour. However, the path of a tornado is seldom much more than 300 miles long and the center travels along 25 to 40 miles per hour. On the other hand, a tornado is tricky; it usually loops back to hit a place more than once while sparing from destruction buildings no farther away than across the street (Fig. 119).

WEATHER CHANGES ALONG A COLD FRONT

Have you ever driven along a road into and out of a thunderstorm within a few minutes? A thunderstorm is a local storm. It is often the result of an advancing cold front. Every experienced camper or boat skipper knows that the tiny alto-cumulus clouds which build up so quickly in a previously cloudless sky may soon become towering anvil-shaped clouds known as thunderheads. Compared to a warm front, a cold front rises steeply from the ground. It covers less territory and brings quick changes in the weather—sudden thunderstorms (which usually occur in the summer), an abrupt drop in the air temperature, and squally winds usually followed by rapidly rising air pressure, clearing skies, and lower humidity.

Cold air masses push warmer air up so rapidly that violent updrafts are produced (Fig. 117). The rapid condensation of moisture in the warm air may produce thunderhead clouds. The upper portions of those clouds consist of ice crystals and their lowest portions produce heavy rains. Some of the rain drops caught in the strong updrafts may be carried to a high level where they may freeze and accumulate a coating of snow or frost thus forming hailstones. Now heavier, these tiny hailstones drop. At lower levels they may gather more weight as water vapor condenses on them and freezes. Hailstones may be blown upward and downward many times. Each time they are blown upward a fresh layer of ice is formed on them. Because of this addition of layers of ice, hailstones the size of baseballs are sometimes formed. Hailstones may be formed whenever a violent thunderstorm occurs. The thunderstorm need not be the result of a rapidly advancing cold front, however.

USING THE WEATHER MAP

You now have enough information about weather conditions to understand a weather map. The daily weather map of the United States Weather Bureau contains a great deal of information upon which weather forecasters have come to rely.

In Fig. 108 on page 158 you will find added information to help you read the different symbols which weathermen use. Every weather map you get from the Weather Bureau will have a section called "Explanatory Notes" which will help you translate some of the more difficult symbols.

Obtain from the Weather Bureau a series of weather maps like that on page 157. By placing one alongside another you will be able to see how highs and lows, air masses and fronts travel across the country (Fig. 118). You will also get a good idea of the job of a weatherman. And you may find that this is the sort of work you will want to do later on in life.

ISOBARS AND ISOTHERMS

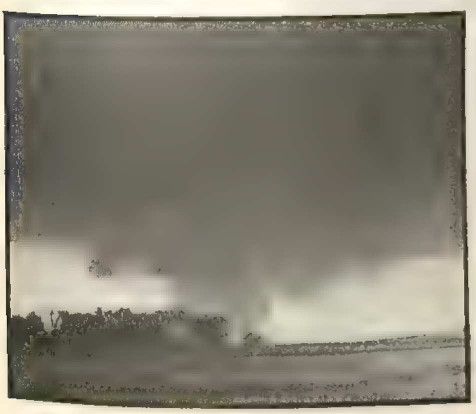
On the weather map on page 157 the peculiar curving lines you see drawn across the map are called *isobars* (ī′sô-bärz). The letters "iso" mean "same"; the letters "bar" come from "barometer." Isobars join places that have reported the same barometric pressure. The closer together they are drawn, the more rapid are the weather changes in the areas they cover.

On winter days, you may also see broken curved lines marked "freezing" or "zero." These lines are *isotherms* (ī′sô thûrmz) joining all places that have reported these temperatures. Isobars and isotherms help anyone reading the map to see at a glance where similar conditions prevail. With this information, plus the readings of your own instruments, plus a glance at the clouds and another at the calendar, plus what you've learned about the cause of weather changes, you should now be ready to try your skill as an amateur weather prophet.

YOUR WORK AS AN AMATEUR WEATHERMAN

Start your work as a weatherman by obtaining daily copies of the weather map. Then make a large chart with spaces for entering all the information obtained on one line straight across

119 *The storm cloud on the left did over $100,000 worth of damage in Iowa. The funnel-shaped cloud on the right, characteristic of tornadoes, was observed during a storm in Kansas.* (*U.S. Weather Bureau*)



the chart. We suggest the following headings for your chart:

Date of entry
Time of entry (or observation)
Present air temperature
Change of temperature since previous reading
Present air pressure (barometric pressure)
Change of pressure since previous reading
Per cent of relative humidity
Change in humidity
Kind of precipitation
Amount of precipitation since previous entry
Direction of wind
Speed of wind
Further remarks about type of wind
Condition of sky
*Type of front coming
*Type of air mass coming
*Approximate speed of coming front (or air mass)
*My position relative to nearest high (or low)
*Weather Bureau's prediction
My prediction
What actually happened

* Obtain this information from the weather map.

You should continue this kind of work till you are able to predict future weather correctly for an average of 75 per cent or better. First, you will have the satisfaction of developing an important new skill, one which may be extremely useful to you. Second, you will be ready to assist the Weather Bureau. Perhaps they will give you permission to hang a sign over your door reading:

METEOROLOGIST—CO-OPERATIVE OBSERVER FOR THE UNITED STATES WEATHER BUREAU

In war and in peace, our country depends upon the work of the amateur weathermen of America (Fig. 120).

120

Meet Henry Ruppenthal, the son of a West Virginia farmer. Henry made the headlines because he was designated a full-fledged co-operative observer of the United States Weather Bureau although he was only 12 years old. He earned his title by sending in complete and accurate weather reports. Are you planning to become an observer? (Wide World Photos)

GOING FURTHER

1 *Comparing centigrade and Fahrenheit thermometers.* Obtain a laboratory thermometer that is marked with both the Fahrenheit and the centigrade scales. Compare the boiling point of water and the melting point of ice on the two scales. Then learn how to change from one scale to another by doing the simple examples using the two formulas given below.

To change centigrade to Fahrenheit multiply by $\frac{9}{5}$ and add 32.

Example: Change 20° C. to F.
$20 \times \frac{9}{5} = 36$
$36 + 32 = 68$

Answer: 20° C. = 68° F.

To change Fahrenheit to centigrade subtract 32 and multiply by $\frac{5}{9}$.

Example: Change 212° F. to C.
$212 - 32 = 180$
$180 \times \frac{5}{9} = 100$

Answer: 212° F. = 100° C.

Now change:

a. 25° C. to F.
b. 50° F. to C.
c. 140° F. to C.
d. 50° C. to F.

2 *Organize a "Weather Bureau" in your school.* Post your predictions daily and compare them with those of official observers.

3 *Make a weather movie booklet.* Draw a map of the United States showing how highs and lows advance across the continent. This can be done by drawing the map about $2\frac{1}{2}$ inches × $1\frac{1}{2}$ inches showing just the outline of our country. Draw it on a piece of cardboard. Cut out the pattern and trace it on 25 or 30 small pieces of paper. Draw in the position of highs and lows as they appear on the daily weather map for about a week. Each one will show the highs and lows a little farther across the continent. Then bind the booklet at the narrow edge and flip its open end with your finger. You will have a weather movie booklet.

4 *Collecting clouds.* If your camera is a type to which you can have filters attached, buy a yellow (K–2) filter and a red filter. Take them along with you on a cloud hunt. Then when you find good examples of clouds of various types, photograph them using the filters. You will discover that your pictures will be dramatic with beautiful high lights and shadows. Enlarge and exhibit the best of your cloud photographs.

5 *Words are ideas.* Can you use these words in a sentence which will give their meaning? Use the glossary.

air mass
anemometer
aneroid
barograph
barometer
Beaufort scale
breeze
calm
cloud forms
cold front
co-operative observer
cyclone
Fahrenheit scale
gale
hail
hurricane
isobar
isotherm
millibar
psychrometer
radiosonde
rain gage
theodolite
thermograph
thermometer
tornado
warm front
centigrade scale

6 *Put on your thinking cap.*

1. Here are certain weather conditions observed in Chicago (or your home town): The barometer is falling, the temperature is rising, the wind direction is changing from west to east and its speed is increasing, the humidity is increasing, and there are low stratus clouds forming. What is your weather prediction? Explain.

2. Name five reliable ways to obtain weather information.

3. Why are the following statements about the weather untrue?

a. A high barometer always means fair weather.
b. Hail is harmless.
c. Dew falls at night.

7 *Test yourself.* In your notebook, complete the following sentences with a correct word or phrase. Do not mark this book.

1. The facts the Weather Bureau gathers include the ...... and direction of the wind, the ...... and ...... of the air, the amount of ...... in the air,

the kind of clouds and their ......, and the number of inches of .... They also want to know the location of cold or warm, wet or dry ...... and the kind of ...... that exists between them.

2. If you were making a mercury barometer, you would need a ...... tube than if you were making a thermometer. The scale of the mercury barometer is marked in ...... while in a thermometer it is marked in ....

3. The mercury in a barometer tube with a cross section area of one square inch will weigh almost ...... pounds at sea level. At the top of a mountain 5,000 feet high, the mercury in the barometer tube will weigh ...... than at sea level.

4. It is more likely to rain when the relative humidity is .... Moisture collects on objects when they have been sufficiently .... The amount of humidity is always expressed as the ...... of water vapor in the air compared to the amount the air could hold if the temperature remained the same.

5. A Beaufort arrow showing a wind of 25–31 miles per hour from the northeast would be drawn thus: ...... on a weather map.

6. Isobars on a weather map are lines connecting places reporting the same ....

7. The oldest method of observing the approach of changing weather without the use of instruments is to observe the .... and note changes in the direction and speed of the ....

8 *Adding to your library.*

1. Write to the United States Weather Bureau c/o the Department of Commerce and request that they send you the class packet on the study of the weather. State that you would like the packet to include, if possible, the booklets "Cloud Forms," "Instructions for Cooperative Observers," and "Weather Forecasting." Read these from cover to cover if you want to learn meteorology.

2. "The Boy Scout Handbook on the Weather" is excellent for those who want to become amateur weathermen.

3. "The Weather—How and Why" as reported daily in the New York *Times* is an excellent publication which you may be able to obtain without charge from the New York *Times* (newspaper).

4. *Weather* by Gayle Pickwell, McGraw-Hill, 1938. Obtain this book, if you like to look at splendid photography. It contains excellent pictures of clouds and other weather elements.

CHAPTER 10

WEATHER BY THE SEASON

There is a season for almost everything—a baseball season, a strawberry season, and a straw hat season. If you investigate, you will find that many events are called seasons because they occur at regular times each year. Even if we limit the discussion to seasons based upon weather changes, you will discover that the number of seasons recognized in various parts of the world varies greatly.

If you lived in Labrador or Scandinavia, for example, you would distinguish only two seasons—summer and winter. The ancient Anglo-Saxons and the primitive North American Indians divided the year simply into cold and warm seasons. In the tropics, wet and dry seasons are the only ones that matter. Some places, such as Burma and India, have three seasons, cold, hot, and rainy. There the rainy seasons and the winds which accompany them are called *monsoons*. The Thompson and Shuswap Indians of British Columbia celebrate five seasons, while the Yukaghir (yo͝o′kȧ gēr′) of northeast Siberia have six. The primitive Melanesians (mĕl′ȧ nē′shănz) of the southwest Pacific have even more. On what basis, then, have we established in the temperate zones the traditional four seasons — spring, summer, autumn, and winter?

WHAT CAUSES SEASONS?

From your daily experience you know that the length of day and night varies with the seasons. During summer the day is longer than the night and in winter the opposite is true. What is the explanation?

UNEQUAL DAYS AND NIGHTS

From Chapter 4 you know that the earth rotates on its axis once every 24 hours (p. 76). Thus one half of the earth is always in the dark and the other half is always in the light. But also, you remember, the axis upon which the earth rotates is not parallel to the sun's axis but is inclined at an angle of 23.5 degrees. The North Pole always points toward the North Star. If you study Fig. 121 carefully, you will see what this tilting of the axis at 23.5 degrees means as far as the length of day and night are concerned. This

figure shows you the position of the earth in summer, winter, spring, and autumn.

As you examine Fig. 121 you will note that during the summer in the Northern Hemisphere, the north polar region is inclined toward the sun. Do you see that in this position the sun's rays cover the entire Northern Hemisphere, while the South Pole is in complete darkness? Therefore, if you live in the north temperate zone, your area spends more than half of each 24 hours in the sun's rays in summer. In summer, the day is, therefore, longer than the night. The reverse is true in winter.

When the North Pole is inclined away from the sun, the South Pole is inclined toward the sun. Thus while the Northern Hemisphere is having short days and winter, the Southern Hemisphere is having long days and summer. At that time the Southern Hemisphere remains longer in the sun's rays. Can you also see from your study of Fig. 121 that at that time the North Pole is in complete darkness? This is so because the North Pole is inclined away from the sun and does not receive the sun's rays. In a real sense, therefore, the length of days and nights varies with the season. In the north temperate zone there are long days in summer, short days in winter.

THE MARCH OF THE SEASONS

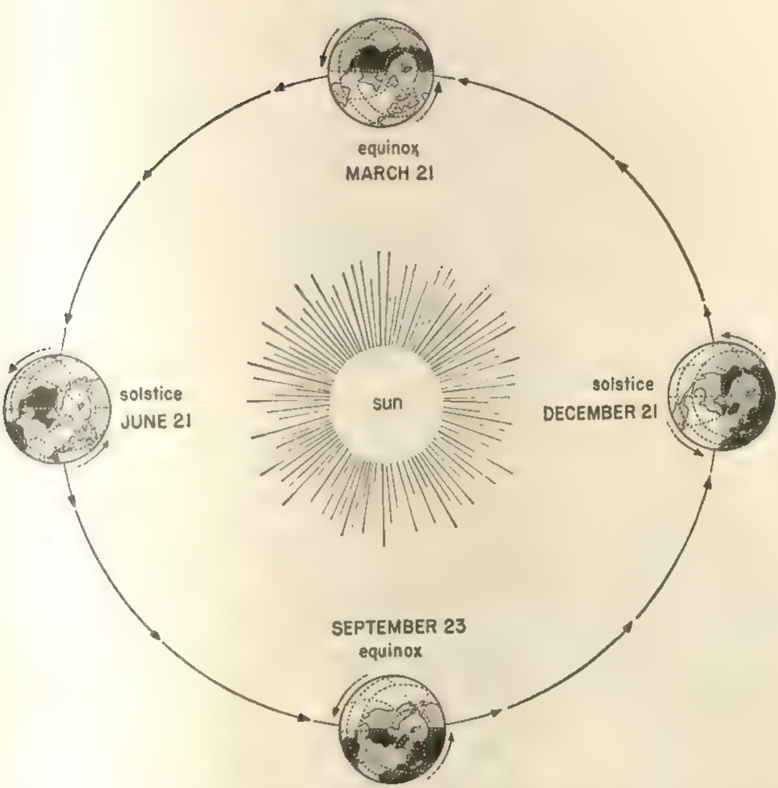
You know, according to the calendar, that March 21 is generally the beginning of spring, that June 21 heralds the beginning of summer, that September 23 prepares us for fall, and that December 21 is the beginning of winter. (These dates may vary by a day or two.) Have you ever asked yourself why the seasons start at about these dates?

The answer lies again in a careful examination of the position of the earth in relation to the sun on these days. Study Fig. 121 carefully as you read this. About March 21 the night in the Northern Hemisphere is the same length as that in the Southern Hemisphere. On that date, at the equator, the sun is exactly overhead at noon. The earth is in the position shown in Fig. 121. As you can see, in this position the axis of the earth is not tilted away from or toward the sun. Therefore, both hemispheres get equal amounts of light on this day. On September 23, the earth is in a similar position but on the opposite side of the earth's orbit (Fig. 121). Again the days and nights in both hemispheres will be the same in length. These two days (March 21 and September 23) are called the equinoxes. "Equinox" in Latin means "equal night."

THE SOLSTICES

From March 21 to June 21, the earth continues its revolution around the sun. Slowly, the North Pole end of the axis inclines 23.5 degrees *toward the sun.* On June 21, the sun at noon appears to be directly overhead at a latitude 23.5 degrees north of the equator. This latitude is called the Tropic of Cancer. About this time the sun appears to remain at this latitude for a few days. For that reason June 21 is called the *summer solstice.* "Solstice" in Latin literally means "sun standing still."

Now if you study Fig. 121 again you will see that in the winter season on December 21, the earth is directly opposite its June 21 position in its orbit around the sun. The North Pole now is tilted 23.5 degrees away from the sun. Now the sun's rays shine longer each day on the Southern Hemisphere. The sun is directly overhead at noon on latitude 23.5 degrees below the equator. This latitude is called the Tropic



121 *This diagram shows the position of the earth in its orbit on the days that mark the beginnings of the four seasons. How much of the earth is always in darkness? On which day does the north polar region have twenty-four hours of darkness? On which day has it twenty-four hours of light?*

of Capricorn. For a few days, the sun appears to remain at this latitude before it starts north again. This time, about December 21, is called the *winter solstice*, the beginning of winter in the Northern Hemisphere. Fig. 122 shows you the apparent path of the sun at noon position over a period of one year. We say apparent path because it is, of course, the earth that moves around the sun. The sun is never directly overhead at noon north or south of a zone 23.5 degrees on each side of the equator. This zone, 47 degrees wide, is called the torrid zone. Why?

The basic reasons then why we have our seasons are:

1. The earth revolves around the sun.

2. The earth's axis is inclined 23.5 degrees.

The angle at which the earth's axis inclines has other effects, as we shall see from studying each season separately. We shall also be able to study in greater detail the characteristics of the four seasons and the way each affects us.

THE FOUR SEASONS

Living things need no official announcement to tell them when a different season has come. Each season has its effects on all living things.

SPRING

For some people, spring is here when little children are allowed to romp outdoors minus leggings and snow suits. Or it arrives when the crocus blooms and boys begin to throw baseballs. Have such statements a place in a science text? Certainly they have, for they are facts as important to science as data concerning the motions of the earth and the slant of its axis. They are important because they concern the activities of living things, activities that are determined by weather conditions.

For those who insist upon a date, March 21 is the official first day of spring. As you remember, on or about March 21, the sun crosses the equator and is straight overhead at noon for all who dwell on that line. On March 21, the spring equinox, the night is the same length in the Northern Hemisphere as in the Southern Hemisphere. The sun rises directly in the east and sets directly in the west. As you can see in the table below, all parts of the world have 12 hours of daylight and 12 hours of darkness on the spring equinox on March 21.

HOURS OF DAYLIGHT

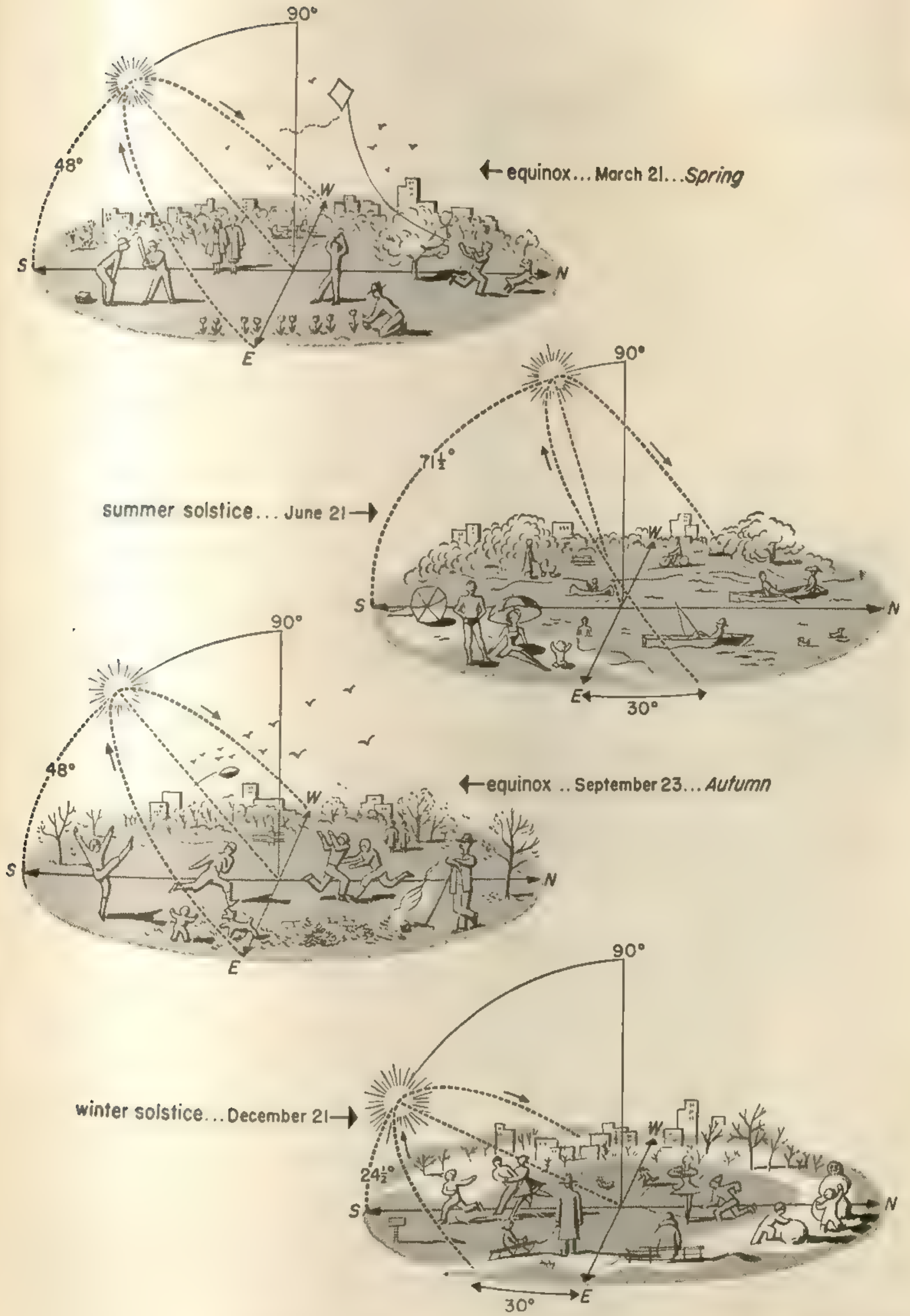
	Dec. 21	Mar. 21	June 21	Sept. 23
Northern Hemisphere				
North Pole	0	12	24	12
Arctic Circle	1	12	23	12
40° N. Latitude	9	12	15	12
Tropic of Cancer	10½	12	13½	12
Equator	**12**	**12**	**12**	**12**
Southern Hemisphere				
Tropic of Capricorn	13½	12	10½	12
40° S. Latitude	15	12	9	12
Antarctic Circle	23	12	1	12
South Pole	24	12	0	12

Notice how the hours of daylight gradually increase in all parts of the Northern Hemisphere from December 21 until June 21. Right there you have part of the explanation for the change from winter weather conditions to summer weather conditions. From December 21 to June 21, the hours of exposure to sunlight increase in the Northern Hemisphere. This increase occurs because the North Pole points toward the sun in these months.

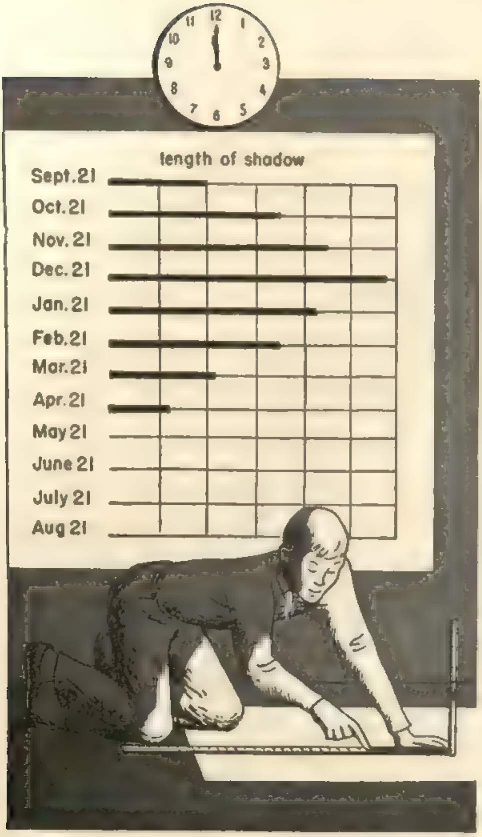
SLANTING RAYS AND CHANGING SEASONS

The other half of the explanation of changing seasons lies in the slant of the sun's rays as they strike the earth. The sun's rays do not really slant. They stay the same. It is the earth that slants. The earth receives the sun's rays in a slanting position. Remember this as we speak, for the sake of convenience, of the sun's rays slanting. Fig. 122 shows how much more the sun's rays seem to slant on December 21 than on March 21 or June 21. You can prove this difference to your own satisfaction by actually measuring the length of a shadow at noon on each of those dates. The boy in Fig. 123 shows you how to do this. The more the sun's rays slant, the longer the shadow. For the same reason a late afternoon shadow is longer than a noon shadow.

The sun's light is more widely distributed as the slant of its rays increases. The boy in Fig. 124 shows you how to demonstrate this. Notice we have suggested that you substitute a flashlight for the sun. Then you won't have to wait three months to complete your observations. Try holding your own flashlight in corresponding positions with relation to the wall of your room. While you do this, have a friend measure the area of the spot of light with a ruler and the intensity of the light with a light meter. A photographer's photoelectric exposure meter may be used.



122 *These diagrams show the position of the sun at noon in the latitude of New York City on the days that mark the beginning of the seasons. On what two days in the year does the sun appear to rise directly in the east and set directly in the west?*



123 *Measuring sun shadows and making a graph of your observations is an interesting activity. Why should all measurements be made at the same time of day? What time is suggested by the clock?*

What do your results indicate? You will find that the area of light is smallest when the flashlight is held perpendicular to the wall. The area of light increases as the flashlight is turned toward a horizontal position. The light meter will show you that the light is more intense when the area it covers is smaller.

Let us assume that in the summer the sun's rays cover an area of 100 acres. In the winter, as the earth's axis turns away from the sun, the sun's rays which covered 100 acres now spread over more than 100 acres. This is so because the sun's rays come in on the slant, thus covering more area, as your flashlight experiment above demonstrated. Since the same amount of sun's heat energy (in winter) covers more area, it follows that less heat will be supplied to *each* acre in the winter than in the summer. Therefore, it will be colder in winter than in summer.

You may have thought that it is colder in winter because the sun is farther from the earth during winter. Actually the earth is closer to the sun in January by some three million miles than it is in July. But since the winter areas receive the slanting, not the direct, rays of the sun, these areas are colder.

As the sun is found higher and higher in the sky from December 21 to June 21, the days become longer. The land, the water, and the air in the Northern Hemisphere are exposed longer to the sun's rays and so absorb more heat from them. Therefore, the temperature increases.

It is also important to note that the sun's rays have a longer journey through layers of the atmosphere when they arrive on a slant than they do when the angle is steeper. Scientists have found that the atmosphere acts as a kind of filter or screen for the rays in sunlight that have the greatest effect upon plant growth and the tanning of our skins—the ultraviolet rays. From March 21 to September 23, when the sun's rays are less slanting, the fewest number of ultraviolet rays are filtered out. This is another reason why spring and summer are not only warm seasons but the best seasons for plant growth.

SPRING TEMPERATURE

Possibly the best description of spring may be put in agricultural terms. A

farmer would say it is spring when life appears to stir in plant cells, when buds begin to open. These stirrings occur when average daily temperatures reach 42.8° F. To most of us, the air feels balmy and springlike when the temperature of the air rises to between 50° F. and 60° F. A study of the average daily temperatures in this country for a period of 46 years showed that average temperatures of 50° F. begin as early as February 1 in some of our Southern states but are not common in northern New England until May 15.

SUMMER WEATHER

As with the coming of spring, the coming of summer is a matter of dispute between farmers and astronomers. The official first day of summer in the Northern Hemisphere is June 21, when the sun seems to appear directly above the Tropic of Cancer, 23.5 degrees of latitude north of the equator. As it is seen from the earth, the sun appears to stand still in its summer solstice for a few days before starting to move toward the equator. See Fig. 122.

When temperatures average about 68° F., summer has come. The man in the street would probably consider temperatures of 75° F. or higher more truly typical of summer weather. Some parts of the United States never experience average summer temperatures over 68° F. Summer temperatures arrive as early as March 1 in southern Florida and as late as July 1 to July 15 in the mountainous sections of the North and West. To some places in the far North of the United States or on mountaintops summer never comes in this sense. *The World Almanac* contains average monthly temperature data for dozens of cities in the United States and its possessions.

In many parts of the United States summer is a season of drought and heat waves. It often brings suffering and death to human beings and their livestock. Crops wither and insects swarm. Newspaper headlines tell the story in the same familiar phrases year after year—NO RELIEF IN SIGHT—HEAT WAVE CAUSES MANY DEATHS—DROUGHT DAMAGE TO CROPS RUNS INTO MILLIONS. And yet summer has its joys—from the swimming hole and beach to exciting baseball games and vacations.

124 *Direct vs. slanting rays of light. Which beam lights up the larger surface area? Which spot of light is the brighter? Why should you reverse the positions of the two flashlights on your second try?*

Widespread summer heat waves and droughts are the result of slow-moving air masses (p. 170). The air masses may reach an almost uniform temperature across the continent. This almost uniform temperature slows down the circulation of the atmosphere. Even when there is sufficient local difference of the air pressure to produce a thunderstorm, the condition of the atmosphere may be as disagreeably hot and humid when the storm has passed as before its coming.

THUNDERSTORMS AND LIGHTNING

Thunderstorms are accompanied by lightning and thunder. Which comes first, the thunder or the lightning? Lightning comes first although many people believe that the opposite is true.

There are many theories to explain how lightning is produced. For our purposes, all we need to understand at this point is that clouds can become charged with electricity. The electrical charges are of two kinds, positive and negative. When the opposite charges become great enough, a spark is produced. It is thought that under special conditions a cloud may develop positive charges in one part, and negative charges in another part. Or one cloud may develop negative charges, another only positive charges. A discharge of lightning may also take place between a cloud and the earth or some object on the earth such as a tree, a person, or a building.

The discharge of lightning heats and expands the air in its path. Air molecules are pushed aside and pressed into a smaller space. As the air expands suddenly and then bounces back, a loud noise is heard. This noise is thunder. The rolls of thunder you hear are nothing more than echoes reflected from masses of clouds.

Standing under a tree during a thunderstorm is an invitation to disaster. At the first hint of an approaching storm, what should you do if you are swimming, or playing golf, or working in an open field? You should seek shelter in a house. If you are in an automobile during a thunderstorm, you need not leave it, for all-metal automobiles are safe shelters (Fig. 125). Beware of parking a car during a severe lightning storm under a tree that may topple over and crush it.

AUTUMN

Autumn begins when the sun is again over the equator at noon, on or about September 23. On this day, you will find that conditions are similar to those at the spring equinox. The length of the day and of the night are equal. As on March 21, the sun rises directly in the east and sets directly in the west. But we know it isn't exactly the same as spring for now the days grow rapidly shorter. At the end of September, daylight saving time is abandoned. Clothes are taken out of moth balls. Hay fever preparations are put back on the shelf. Fireplaces are lighted and thoughts turn to Thanksgiving—"When the frost is on the punkin and the fodder's in the shock."

The weatherman has another way of marking the turn of the seasons. He does not go by the calendar but by the thermometer. Autumn for him has two parts in the months of September, October, and November—Indian summer and the cool fall. When air temperatures are between 67° F. and 50° F., we have Indian summer. The cool fall days are those when the temperature hovers between 50° F. and freezing. The temperatures for autumn days average about the same as those for spring days. Along seacoasts the slow cooling off of

125
Three million volts of artificial lightning hit this car in the Westinghouse Laboratories at Trafford, Pennsylvania. The stroke can be seen jumping over the left front tire to reach the ground. Why is your car a safe refuge in a thunderstorm? (Westinghouse Electric Co.)

the ocean and other large bodies of water has the effect of prolonging the warm weather of early autumn because the water retains the summer heat. The slow warming up of the oceans in spring prolongs the cold weather of winter in coastal regions.

One more factor accounts for some of the surprisingly mild days of autumn. The warm air masses of the tropics seem to be able to come farther north more often than they do in the spring. Whenever one of these air masses manages to go north it makes the weather milder than the seasonal average.

DEW, FOG, AND HURRICANES IN AUTUMN

For what other conditions is the autumn noted? This can be answered in three words—dew, fog, hurricanes. Hurricanes have already been described on page 171. Fig. 126 illustrates the kind of damage that a hurricane can do. September and October are the principal hurricane months along our southeastern and eastern coasts.

Dew and fog have also been mentioned previously, and now we are ready to study them in more detail. What kind of weather increases the formation of dew and fog? Dew is the hallmark of fair weather. If you see a heavy dew, you may be sure the night has been clear and calm. If the night is windy, dew forms with difficulty for wind causes water to evaporate quickly. Therefore, a heavy morning dew means that the night was calm, not windy.

The same is true for the formation of frost. When the temperature of the air near the earth is below freezing, frost rather than dew is deposited.

Fog usually forms in the early morning. It can form at any time, however, but forms most easily when damp (humid) air is cooled. Like dew, fog forms best when the air is not too windy. The gentle mixing of cold air with warm humid air or the rapid cooling of warm humid air will produce fogs. Night-formed fogs usually disappear when the sun comes up with sufficient strength to evaporate the tiny droplets of moisture which form a fog.

The presence of smoke in the air, on the other hand, encourages the formation of fog because the droplets of moisture have more dust particles upon which to condense. Combinations of fog and smoke, often called smog, are much worse to deal with because the tiny smoke particles are present in tremendous numbers. Smog is, therefore, not dispelled as easily as is fog. During the war, landing fields in England were cleared of fog by the heat produced by burning large amounts of gasoline—a costly method. Now it is hoped that sprinkling dry ice or fine sprays of water from airplanes will produce an inexpensive method for clearing away the clouds that surround airports. Maybe the problem will be left for one of you to solve!

WINTER

For many people, winter is the best of all seasons. Astronomers say it begins on December 21 in the Northern Hemisphere. On that day, as you remember, the sun is above the Tropic of Capricorn at noon (Fig. 122). The sun is low in our sky at noon, rising late and setting early. The shortest day in the year is the first day of winter. Yet there is reason for rejoicing, for now the days can only grow longer. The origin of the holidays shortly after the winter solstice may be traced to the ancient festivals which celebrated the beginning of the longer days.

Nevertheless, in the Northern Hemisphere the coldest days of the year come in January and February when the days are noticeably longer. During winter the northern latitudes usually are covered with a blanket of snow. Snow forms only when the temperature of the air causes water vapor to crystallize below its freezing point. A winter day is considered as one in which the average temperature of the air is 32° F. or less. Some parts of the United States have this average daily temperature as early as November 20, others as late as December 15, and still others seldom experience this temperature at all. Yet even in many of our Southern states where the temperature of the air normally remains above 32° F., farmers have only to look at their crops to know when winter has arrived.

LIVING THINGS AND SEASONAL WEATHER

Not all animals can stand the seasonal weather the way we do. Some warm-blooded animals are equipped to stand cold weather and remain active all winter. Others migrate or hibernate. Fish and frogs, you remember, are cold-blooded. This means that their body temperature goes down as the temperature of their surroundings goes down. For them it is fortunate the ice in a pond floats, leaving a certain amount of water and mud unfrozen at the bottom. Here they stay throughout the winter living on food stored in their bodies. Otherwise they would freeze to death.

ADAPTING TO BAD WEATHER

Plants also have temperature limits within which they can live. Some plants like orange trees, orchids, and jungle plants do not grow in the northern parts of our country. They need warm, moist weather. The plants that do live in the north become dormant during cold weather. During the dormant stage, many trees lose their leaves. Other trees, such as the evergreens, keep their leaves but make little or no food during the coldest weather. They live on stored food.

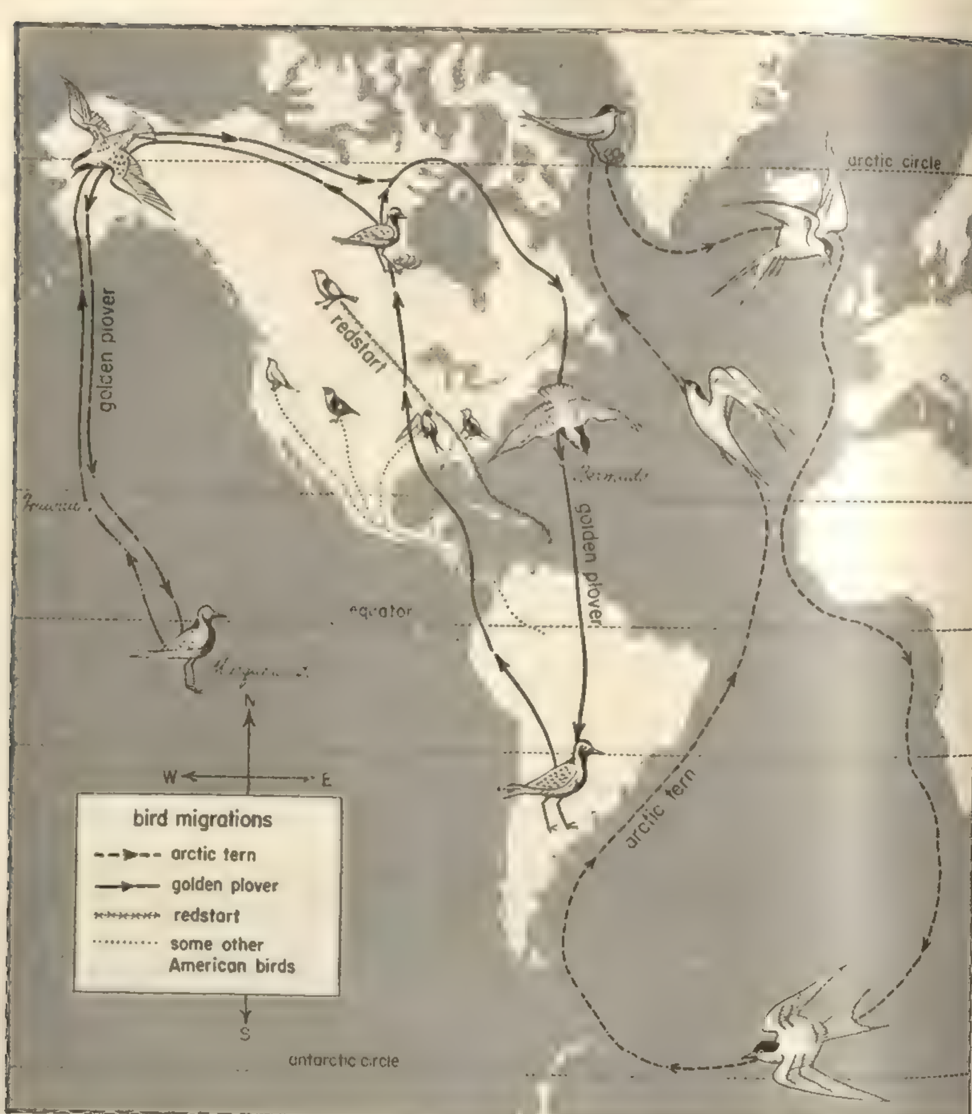
Many animals, like certain birds and the monarch butterfly, go south when the winter kills the plants that feed them. Fig. 127 shows you how far some birds migrate. How they do it is a mystery still to be solved by the co-operative work of scientists in nations to which the animals migrate.

Yet these yearly mass flights are no more astounding than some of the sleeping done by so many thousands of animals during the cold months. This winter sleep is called *hibernation* (hī′bẽr nā′shŭn).

A female black bear hibernates in such a deep sleep that she can give birth to cubs and not be aware of it till spring. Many types of insects hibernate. Other insects pass the winter as eggs, larvae, pupae, or nymphs hidden in the ground, in rotten wood, in water, or in the bark of trees.

It all sums up to this: If you want to live in any region, you either have to like the weather, ignore it, or endure it. Some animals, such as lizards and snakes, crawl under rocks to hide when the sun is too hot. Others, like the woodchuck, crawl underground and "sleep the clock around" when the

126 *This photograph shows the extent of the damage caused by a hurricane that struck Mattapoisett on the shore of Buzzards Bay, Massachusetts. (U.S. Weather Bureau)*



127 *Migration routes of long-distance bird travelers are shown on this map. Notice what amazing distances the arctic tern and the golden plover fly each year.*

weather is too cold. Some animals, such as the golden plover, fly thousands of miles across continents and oceans when weather conditions change (Fig. 127). Others—people we know—spend their summers on New England beaches and then migrate to Florida or to California to spend their winters; and others change their indoor weather.

MAINTAINING A SATISFACTORY ENVIRONMENT

Where weather conditions are unsatisfactory, people must maintain an artificial indoor environment in which to live. They do this by building satisfactory houses.

Before you can make a house a home, you have to make the house a shelter from the changing weather. It is in this

sense that we shall consider the problem of better housing in the next chapter. Since we cannot obtain perfect outdoor weather when the seasons change, let's find out what we can do about obtaining satisfactory indoor weather regardless of the season.

GOING FURTHER

1 *Temperatures in your community.* Take an average of the highest and the lowest temperature in your community for each day. Using the temperatures mentioned in this chapter, find out when each season begins and ends in your part of this country. Compare this actual beginning and end of the seasons with the calendar dates assigned by the astronomers.

2 *Water and air temperatures.* If you live near a large body of water, make a daily record of the temperature of the water and compare this with the temperature of the air by plotting a line graph for each on the same piece of graph paper.

3 *Plants and temperatures.* Compare the leaves of an evergreen with those of a maple and with the exposed portion of a cactus plant. How is each adapted to the kind of weather conditions it encounters?

4 *For the photographer.*

1. Choose several scenes of activity, such as a schoolyard, a market place, a farm, or a park, and photograph each first, at the dates of the change of the seasons and second, at midseason. Use the same camera position in each case. These are the dates: February 5, March 21, May 5, June 21, August 5, September 23, November 5, and December 21.

2. Make a panorama photograph of the western horizon, being careful to set up your camera in the same spot on each of three times in the year, one equinox and two solstices. In a panorama picture, the edge of one picture is pasted over the edge of the following one to make one large picture. Trim the finished prints so that when you mount them they will look like one picture. This will give you evidence that the sun sets north of west during one half of the year and south of west during the other half. The data in Fig. 122 will help you to explain why this happens.

5 *Words are ideas.* Can you use these words in a sentence which will give their meaning? Use the glossary.

cold-blooded animal	migrate
environment	monsoon
equinox	season
hibernate	smog
dormant	solstice
lightning rod	warm-blooded animal

6 *Put on your thinking cap.*

1. Why does the Northern Hemisphere have its warmest weather during July and August at a time when the earth is farthest away from the sun?

2. What would be the probable effect upon the earth and upon living things if the slant of the earth's axis should increase to 50 degrees or decrease to 5 degrees?

7 *Test yourself.* In your notebook, complete the following sentences with a correct word or phrase. Do not mark this book.

1. When living things cannot flee from weather changes that are unfavorable to them, they must ...... Some animals, such as ......, migrate as the seasons change. Other animals, such as the black bear, ... when winter comes.

2. Astronomers say the seasons change on ......, ..., ..., and ...... These dates are based upon the position of the ...... in the sky.

3. Because land warms up and cools off more ...... than water, places near large bodies of water have ...... winters than places in the center of a large continent.

4. All seasonal changes are the result of the ...... of the earth around the sun every $365\frac{1}{4}$ days and the ...... of the earth's axis.

5. One of the most noticeable seasonal changes is the length of the hours of daylight which are longest on or about ...... and shortest on or about ...... For the same reason, there are 12 hours of day-

light and 12 hours of darkness throughout the year at the ......, and nights are of equal length in both the Northern and Southern Hemispheres on ...... or ....

8 *Adding to your library.*

1. Write to the Superintendent of Documents in Washington, D.C. for a copy of *Normal Weather for the United States* by J. B. Kincer (10 cents). This booklet published in 1943 by the United States Department of Commerce is an authoritative account of the kind of weather to be found in the various parts of this country month by month throughout the year. It is a reference book any committee reporting on this topic will need.

2. Consult Cornell Rural School Leaflet No. 3, Vol. 37, January 1944. As its title "Little Climates" suggests, it discusses the effect of small changes in climate upon plants and animals.

3. "How They Beat the Heat" by C. M. Bogert. This is an interesting article on the way in which desert reptiles escape death from the heat of the sun. Read it in the *Natural History Magazine*, June 1939.

4. Write to the National Audubon Society, 1005 Fifth Avenue, New York 28, N.Y. for a list of their pamphlets on how plants and animals survive the winter. All are well written and instructive. Perhaps you will want to make use of the information to build some shelters for birds and other animals found in your neighborhood.

CHAPTER 11

PROTECTION AGAINST WEATHER

Primitive man could never have explored the South Pole. He would have frozen to death. But Admiral Byrd and the men in the expedition he led to Antarctica lived there for months at a time in fair comfort. Primitive man was at the mercy of his environment. He was really at home only in the tropics. He dared the colder northern regions only when he learned to build fires. Even then he was at the mercy of the weather, for he did not have suitable clothing or housing.

Modern man, however, is more and more able to control his environment. His houses represent efforts to secure perfect indoor weather for his health, perfect temperature, perfect humidity, and perfect ventilation. His clothing is an attempt to meet outdoor weather at its worst or best—clothing which will keep a person warm in cold weather, dry in wet weather, cool in warm weather. This chapter deals with the scientific principles that govern our choice of clothing and housing.

CLOTHING

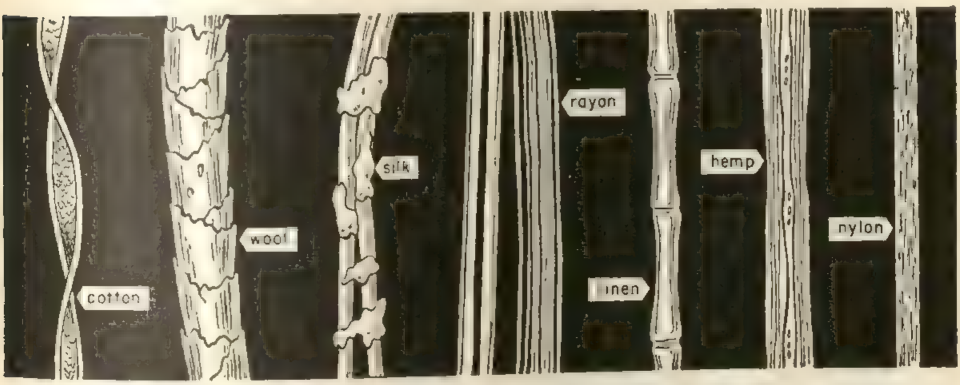
One of the first principles of science states that every substance, every material has its own characteristics. The characteristics of a brick or a piece of paper or a pile of sand make them useful as building materials. Likewise, characteristics of a bit of cloth, a piece of leather, or a pelt of fur determine what kind of garment will be made or how it will be used. What are the special characteristics of the materials which we use to protect us from unpleasant weather conditions?

CHOOSING MATERIALS FOR CLOTHING

It is easy to understand why leather is used to make windbreakers and gloves. Leather is a material which wind cannot easily penetrate. It is almost as easy to understand why fur is used for garments to keep us warm. Dead air spaces, in which air cannot circulate, are created by the overlapping of the hairs in the furs. When air cannot circulate, it provides good protection against the loss of heat. Fur garments, therefore, help us to retain the heat of our bodies.

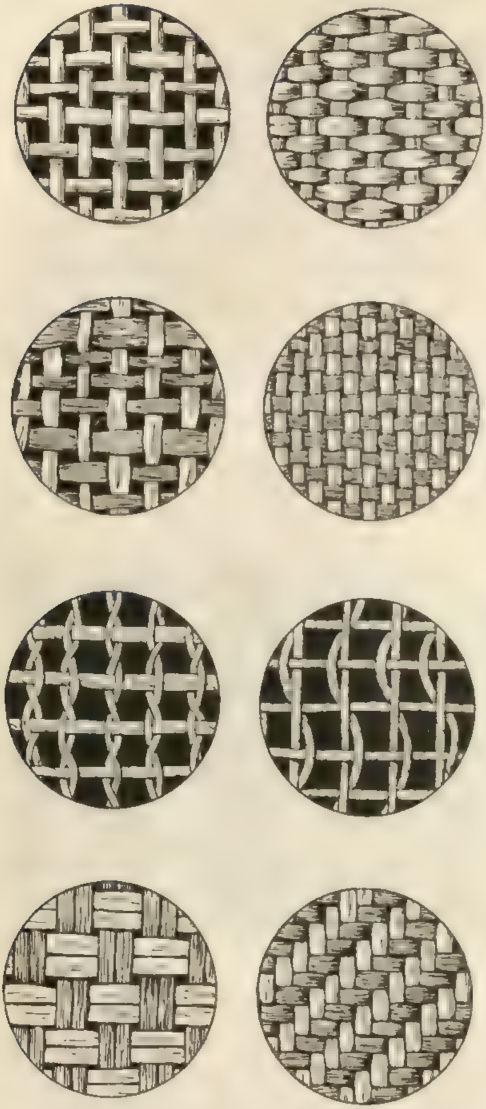
For exactly the same reason but to a lesser extent, cloth woven from wool keeps people warm. Examine a bit of wool under a microscope or even under a hand lens and you will see the hairy appearance of the fibers. The tiny air spaces between the fibers act as an insulation, or barrier, to the escape of heat from the body. Can you recognize cotton, silk, and linen, or any of the man-made fibers such as nylon and rayon, under the microscope? Fig. 128 shows you the appearance of each of these fibers. But it is the air spaces between masses of these fibers which help keep us warm. At the end of this chapter, you will find references describing the properties of each of these materials from which textile fabrics are woven. Study these before you buy more clothing.

128 *These are drawings of seven common fibers as seen under a microscope. Does this help you to understand why woolen goods usually feel rough? Why are rayon and nylon so smooth?*



DESIGNING CLOTHES FOR PROTECTION AGAINST THE WEATHER

If the choice of material is the first consideration, the weave of the cloth is the second consideration (Fig. 129). Take out your handkerchief. Hold it up to the light. Can you see the light through it? Repeat this test with single layers of the materials in the garments



129 *These drawings show how various common weaves look when examined under a microscope or reading glass. The top four are all plain weaves but they differ in quality because each has a different thread count per inch. Which do you think will wear the longest? The two very open weaves are used in lightweight curtains. At the bottom is a basket weave used in Oxford shirts and a twill weave used in suits.*

you are wearing. Do you notice any difference in the size of the spaces between the threads or fibers? Is the home-knitted sweater you are wearing woven as tight as a blanket? Compare the weaves of the garments you wear in summer with those you wear in winter. Do you suppose the closeness of the weave has anything to do with keeping you warm (Fig. 129)?

Now look at the color of the materials you are wearing. What color should you wear to be cool? Make this test yourself. Take two pieces of the same kind of material, one white, the other black. Now place both pieces of cloth in the direct rays of the sun. Under each place a thermometer. Check the temperature at the start of the experiment and at the end of various intervals of one to five minutes. You will find that the thermometer under the piece of black cloth will show a considerably greater increase in temperature. Dark colors absorb radiant energy more readily than do lighter colors. White, for instance, reflects a good deal of radiant energy. What colors, weaves, and materials would you wear in summertime? in wintertime?

The finish and fit of clothes also have a great deal to do with our comfort in wearing them. You may not realize it but you perspire in winter just as you do in summer. The difference is that in summer you notice it more because hot and humid air contains so much moisture the water cannot evaporate as rapidly as it leaves your sweat glands. Therefore, it collects on your skin and dampens your clothes. In winter, the dry air permits the moisture to evaporate from your sweat glands as rapidly as it forms.

But evaporation cools our bodies. Do you remember how it causes the temperature of the wet bulb of a

psychrometer to drop? Do you know why you shiver in a wet bathing suit? Then you will understand why winter clothing is heavier and why summer clothing is lighter—heavy clothing retards evaporation and light clothing facilitates it. All these things—fiber, weave, finish, fit, color, and weight—should be considered if you want to dress properly for each season.

ACCESSORY CLOTHING FOR PROTECTION

Style more than seasonal weather changes may dictate our choice of clothing accessories. Probably that is the explanation for women's use of furs in summer and open-toed shoes in winter. In summer, the general rule for comfort should be the fewer clothes, the better. But in cold weather, accessories such as rubber overshoes, sweaters, scarves, and gloves may give real protection if they are properly used.

Gloves, for example, will not keep hands warm if they fit so tightly that they hinder the circulation of blood in the fingers. Did you ever tie a string around one of your fingers and leave it there for two minutes? Even though you are in a warm room, your finger will become cold. Without proper circulation of the blood, you cannot keep warm. For winter wear, therefore, choose gloves that are not too tight.

Rubber overshoes, unlike ordinary shoes, permit no evaporation of moisture when your feet perspire. They keep moisture both out and in at the same time. If you wish to avoid the consequences of wet feet, wear overshoes but do not wear them too long at a time. Take them off when you are indoors so that evaporation can take place. For the same reason, it is a good idea to wear perforated shoes in summertime. The holes permit better circulation of air and thus better evaporation.

HOUSING

Man invented clothing to protect himself against changing weather. He invented houses in an attempt to create conditions in which he could work and rest with maximum comfort.

You can readily see that strong sheets of solid material like painted steel can keep out the rain. But unless it is specially treated or coated, steel will not keep out the heat or cold. In order to understand why this is so, we must understand the principles which underlie all methods of keeping a proper temperature at home. These methods are conduction, convection, and radiation. Simple experiments will help us understand each one of these methods.

CONDUCTION

If you were to take a piece of metal, like a long iron nail, and heat it in a flame, you would soon drop it. Iron conducts heat. You remember that all substances are composed of invisible units called molecules and that these molecules are in motion. When a substance is heated, its molecules begin to move more rapidly. Scientists think of heat as the movement of molecules. In the nail, molecules of iron are heated by the flame. This causes them to move about rapidly and jostle other molecules next to them and so on right along the nail. In this way, the heat reaches your fingers. The transfer of heat in a solid by moving molecules is called *conduction*.

Metals are good *conductors* of heat for the very reason that their molecules are set in motion very easily. Thus when metals like copper, iron, or zinc are heated as by a gas flame, hot water, steam, or the sun they warm up quickly because the heat is *conducted* quickly through them.

130
The snow-blanketed roof is a well-insulated roof. Why? (*Johns-Manville*)

On the other hand, wood, air, glass, cotton, and wool are poor conductors of heat. Their molecules are not easily set in rapid motion. Therefore, you could heat the edge of a screw driver in a flame and hold its wooden handle for some time before you felt the heat. Also any material with air spaces in it is a poor conductor of heat. Storm windows placed over the house windows enclose a dead air space between the two panes of glass. This dead air space reduces loss of heat through the house windows.

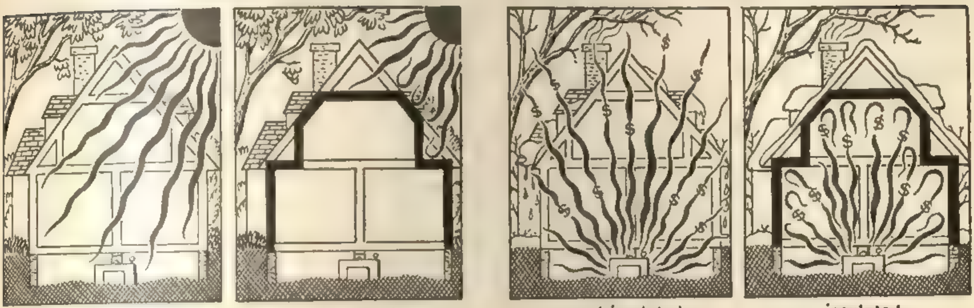
When a house is built, insulation is added to the walls and roof for the purpose of keeping the heat inside in winter and outside in summer. A well-insulated house has a layer of glass wool, rock wool, or porous board in its walls and roof. All of these materials hold air between their fibers or pores. Since air is a poor conductor of heat, heat leaks out more slowly through the walls or roof in wintertime, and gets into the house more slowly in summer. A good way to test whether a roof is well insulated is to notice how long its blanket of snow lasts. If it melts quickly, then heat is leaking through the roof rapidly; it is not well insulated (Figs. 130 and 131).

You also see why a roof made of galvanized iron which is not insulated is a poor roof. It keeps out the rain and snow, but in summer it conducts the sun's heat right into the house. In the winter, it conducts the heat out of the house into the cold outer air.

However, in spite of the fact that air is a poor conductor of heat, we depend on movements of air to heat our homes by convection currents.

CONVECTION

The metal of a radiator or hot-water pipe is heated throughout by conduction. So is the air immediately around the metal radiator. As air is heated, its molecules are set in motion away from the radiator. Then cool air moves into the space vacated by the heated air. This process results in a continuous current of falling and rising air. This cur-



131 *These diagrams show that a well-insulated house is an asset in winter and in summer. Which will be cooler in summer? Which will cost more to heat in winter? (Johns-Manville)*

rent is called a *convection current.* And the transfer of heat by convection currents is called *convection.* In conduction, the heat is passed along from molecule to molecule; in convection, the mass of molecules itself is carried to a new place and thus carries the heat with it. Hence, in any heated room, there will be a circulation of air.

You can see why some farmhouses have grates or registers in the floor right over the stove or furnace. The convection currents in the air rise and enter the register above the stove, thus helping to warm the room above. You can also see why hot-air heating systems should have two openings in the room, one to admit the heated air and one to return the cooler air to the furnace. The colder, heavier air enters through the bottom, is heated, and leaves through the top opening. Thus a circulation of heated air is insured.

Just as air carries heat by convection, so does any fluid whose molecules move in mass. Water, for instance, circulates in this manner in hot-water systems (in boilers, radiators, water pipes). Masses of water molecules when heated rise as they are replaced by masses of cold water molecules. Thus a circulation of hot water by convection is set up. In the apparatus shown in

132 *Convection currents produce circulation of the water in a model hot-water heating system. How can we tell that the water is circulating?*

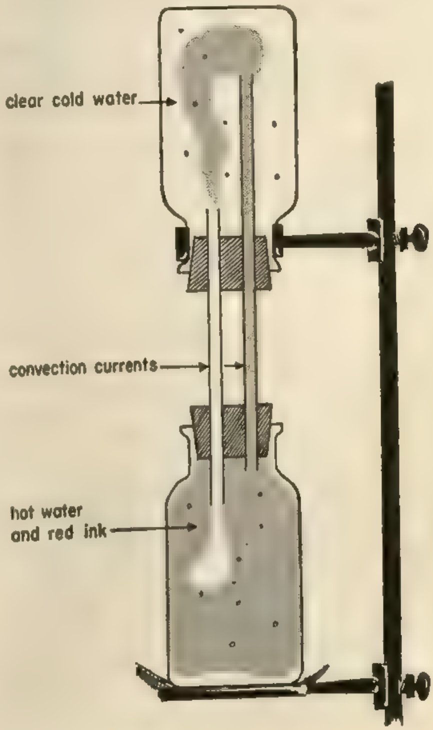


Fig. 132 you see how convection currents in water can be demonstrated in the classroom.

RADIATION

. People who have fireplaces often complain that the fires heat the front part of their bodies only; their backs are cold. Furthermore, they find that the air in the room is cold but that solid objects, pieces of furniture or metal near the fire, are warm. This is true because a fireplace does very little heating by convection or conduction but instead it heats by *radiation.* Radiant heat is not due to moving molecules but to waves of radiant energy. Radiant heat is effective only when radiant energy is absorbed by a body exposed to it. Thus the air in a room heated by a fireplace may be cold because it does not absorb the waves of radiant energy. Objects in the room are warm because they do absorb the radiant waves.

The waves of radiant energy travel with the speed of light, that is, 186,000 miles per second. When they reach a solid body and are turned into heat, they speed up the motion of the molecules of the body they strike. These molecules heat others near them, and the body is heated by conduction.

As you learned (p. 153), the sun heats by radiation. Hot radiators, hot stoves, and electric heaters also send out waves which heat by radiation. You probably have read of heating systems which depend on radiation. In radiant-heating systems, coils of pipe for hot water or steam are cemented into the walls, floor, or ceiling. When these pipes or cables are heated, the surfaces radiate energy which is given off into the room and is absorbed by solid objects. These solid objects, such as people, chairs, and rugs, are warmed as radiant energy is turned into heat. Heating by this method seems to be economical. It certainly eliminates smoke and dirt carried by convection currents from stove or furnace. But radiant heating is still in the experimental stage and there are a number of disadvantages to overcome.

INDOOR WEATHER TO ORDER

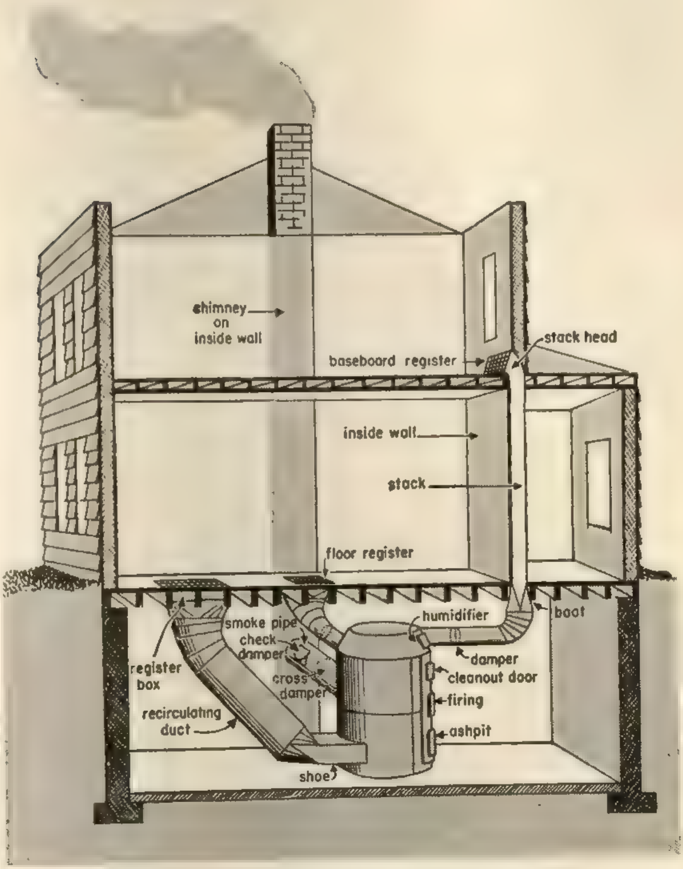
The first efforts to heat homes in winter consisted chiefly of trying to warm the air inside by means of an open fire. Some of the smoke from the fire escaped through smoke holes cut into the ceiling. Much of the smoke remained in the cave, tepee, tent, or room.

The first fireplaces with chimneys to carry the smoke out of doors were invented in the Middle Ages. Later, grates were added for better draft. Finally, stoves which could burn wood, oil, or gas were invented. Today the majority of homes in the northern United States are heated by a system that heats the entire house. Such systems are called central heating systems.

COMPARING CENTRAL HEATING SYSTEMS

A central heating system is an arrangement whereby heat generated in one central place (usually the basement) is distributed throughout the house. There are several types of central heating systems. Each has its special advantages and disadvantages. Everyone who is likely to live in, own, rent, or build a house with central heating should be familiar with the facts about the various systems.

There are three main types of central heating systems: hot (or warm) air, hot water, and steam. In a hot-air



133

A hot-air heating system. The heavier cold air sinks into the register and large ducts while the hot air rises. Why is this type of heating system least expensive? Which room may become too hot? (Household Finance Corp.)

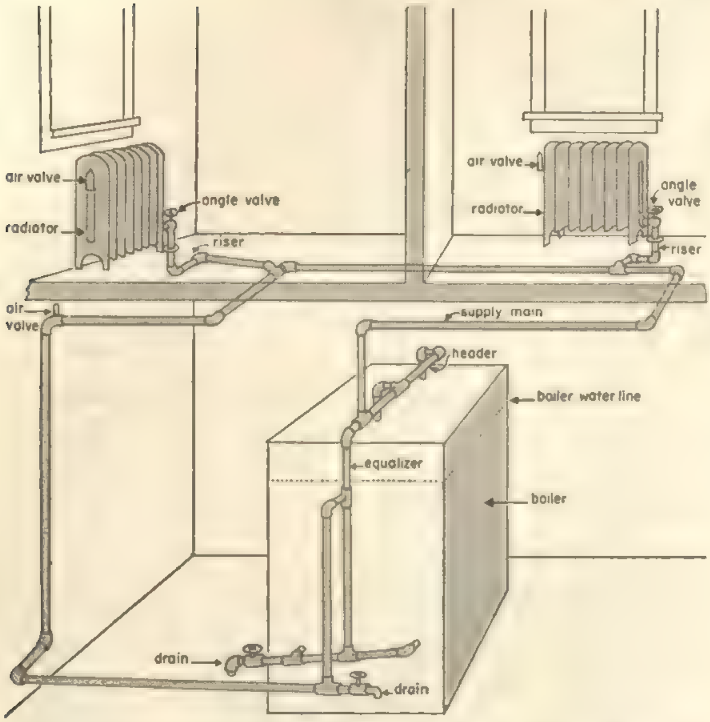
system, air is heated and circulated (Fig. 133); in a hot-water system, hot water is circulated; in a steam system, the water is turned into steam, which is circulated (Fig. 134).

Each system, however, employs a furnace, which in itself presents problems. Regardless of the type of system used for distributing the heat, the homeowner must decide whether he will use a gas-, oil-, coal-, or wood-burning furnace. Which type of furnace is best should be decided after considering the cost and availability of the fuel. This depends largely upon where you live. For instance, oil, coal, and gas are readily available in most parts of the country, wood in others. A second consideration must be the amount of time and energy the homeowner can give to taking care of the furnace. Can you figure out why oil and gas are the fuels often preferred?

HOT-AIR SYSTEMS

In the first hot-air systems, fresh air entered from the outside and was heated. Now the air of the house goes back into the system and is reheated. Reheating saves fuel and keeps the air in circulation but it also causes the air to become extremely dry. Water vapor is added to the air by a humidifier, which is usually a pan of water placed in the air-warming jacket that surrounds the furnace (Fig. 134).

In the hot-air heating system, the hot air generally circulates through large



134

A one-pipe steam-heating system. Why do the "horizontal" pipes slope slightly? (Household Finance Corp.)

ducts (Fig. 133). Some hot-air systems use a motor-driven fan to circulate the air.

HOT-WATER HEATING

The great advantage of the hot-water heating system is that you can bank the furnace early and yet have a warm house for many hours. The water will remain warm. What is the disadvantage of a hot-water heating system? People who want their houses to be warmed quickly on cold mornings prefer a hot-air system or a steam-heating system. These heat more quickly but they also cool more quickly than does the hot-water system. Some hot-water systems use pumps to help circulate the hot water but these are not always necessary. Hot-water systems have the advantage of providing uniform and steady heat because of the heat-holding capacity of water. They are more expensive to install than other systems.

STEAM-HEATING SYSTEMS

A steam-heating system is a closed system. It has to be a closed system to build up the necessary pressure. Never try to make a true working model of a steam-heating system using glass flasks and tubing. Always leave the system open at some point as in Fig. 135. If the pressure becomes too great, a closed system made of glass parts may burst. Even a real steam boiler made of iron may burst if the pressure is not properly regulated. Safety is assured by a pressure release valve on the boiler which makes a steam-heating system as safe as any other.

Like hot-air systems, steam heating provides a quick method of heating a house. If you were to operate the safe model steam-heating system shown in Fig. 135, you would notice how little time it takes to heat the flask (radiator). Notice also how quickly it cools again after the flame has been turned off.

Now look at a real steam radiator. It may have one pipe or it may have two pipes connecting it to the furnace. But the heater pipes and radiators of a steam-heating system are almost like those of the hot-water system. The boiler, however, is kept only partly full of water so that steam can be formed easily above the water. The steam rises in the pipes (Fig. 134). In hot-water systems, the pipes, of course, are full of water.

All things considered, what kind of heating system is best? You alone can answer that question for your own house. However, we can tell you that these are some of the things you will need to consider: performance, original cost, operating cost, and cleanliness. This is the kind of problem a committee of students can investigate. Send for information from manufacturers of heating systems and compare the facts you obtain. Then report your findings to the class and to your parents.

AIR-CONDITIONING SYSTEMS

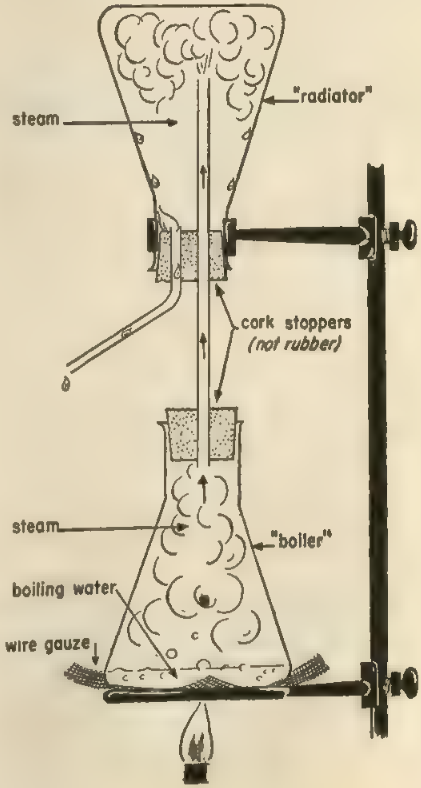
Most people who live in civilized communities are able to solve their heating problems. One way or another, whether by a fireplace, stove, hot air, hot water, or steam heating, their homes are heated in winter. But heating is only one problem. Men want a system which will keep their houses well ventilated at an even temperature and a comfortable humidity at all times, spring, summer, fall, and winter. In short, they want perfect weather at home.

At the beginning of this unit, you learned that outdoor weather was caused by air in motion. From your reading in this chapter you may have already concluded that indoor weather depends upon the condition of the indoor air. Indoor air carries moisture, it is heated by convection currents, it carries odors. If we can keep this air at the proper temperature and humidity, and circulate it gently, we will be treating or conditioning the air for good health. This is known as complete air conditioning.

FIRST EXPERIMENTS IN AIR CONDITIONING

Not until 1912 did scientists obtain experimental evidence on what we now call complete air conditioning. The New York State Commission on Ventilation sponsored a test with the

135 *Glass model steam-heating system. Notice that in this model a return pipe is left open so the pressure will not become great enough to blow the model apart.*



co-operation of the College of the City of New York. The students of that college volunteered to live for a while in a specially built room. This sealed room served as a test chamber, for in it all sorts of weather conditions could be created and controlled. The temperature, the humidity, the circulation, and the cleanliness of the air were regulated at will. Of course the reactions of the students were observed and their opinions written down.

What were the results? It was discovered that a temperature range of 66°–68° F. is the most comfortable when the humidity is kept between 30 per cent and 60 per cent. The ideal humidity is 50 per cent.

It was discovered that the air in a room should be kept in gentle circulation but that drafts should be avoided. It is important that you understand the reason for this. Drafts cause portions of our bodies to become chilled but a gentle circulation of air prevents the formation around us of an "envelope" of warm, humid air which makes us feel sleepy. If possible, the dust should be filtered out before the air is circulated.

By 1925, engineers had discovered how to create perfect indoor weather conditions in theaters, public buildings, and homes. Unfortunately, there is a high price tag on this scientific achievement and the cost of perfect year-round indoor weather is still too great for most private homeowners. Within another twenty years, complete home air conditioning may become as common as central heating is now in some parts of our country. In many cities stores and office buildings are being air-conditioned.

136 *Ice may be made when a refrigerant is evaporated quickly. The ether gets the heat needed for evaporation from the watch glass and the water. The cork acts as insulation. Why must there be no flame in the room when this experiment is tried?*

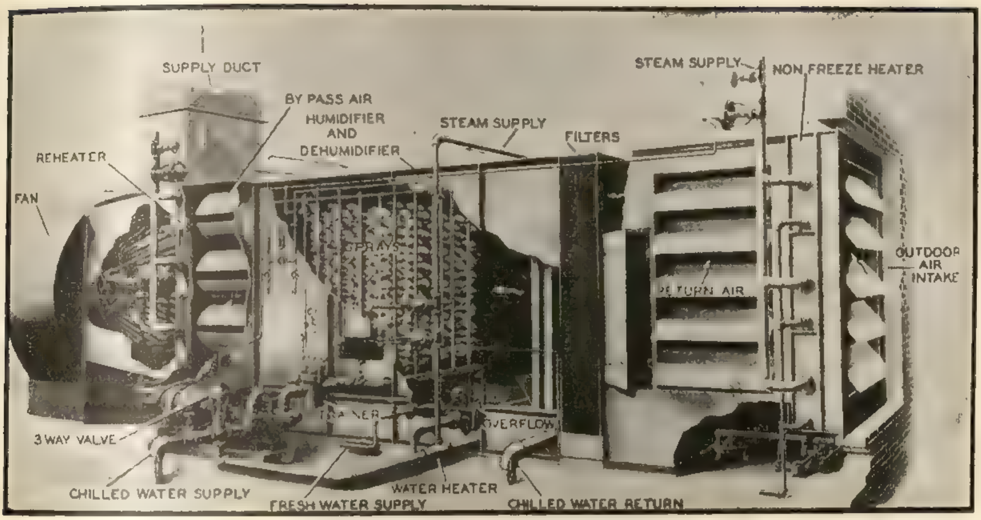
COMPLETE AIR CONDITIONING IN EVERY SEASON

The adding of heat to cold indoor air is one problem, removing the heat from warm air is another. Let's try a simple experiment to show how heat is removed by a refrigerant.

Place a drop or two of pure water on the upper surface of a cork. Put a watch glass on top of the water. Now pour a few drops of ether into the watch glass. Quickly fan the ether and make it evaporate rapidly. In a short time, you will discover that the ether has vanished and that the watch glass is frozen to the cork (Fig. 136). What changes have taken place?

First, the water lost its heat to the ether. Second, the heat caused the ether to change from a liquid to a gas. But these two things happen at the same time, not separately.

One type of air-cooling system operates on an evaporation principle similar to the experiment you have just done.



137 *A view of an air-conditioning unit for a large building or theater.* (*Carrier Corp.*)

A liquid called a *refrigerant* is made to change from a liquid to a gas as it circulates through a system of pipes, closed so that the process can be continued without loss of the refrigerant. The refrigerant, a liquid under pressure, is allowed to evaporate. The change in the condition (state) of the refrigerant from a liquid to a gas requires heat just as water does when it evaporates. The heat is drawn from a solution of salt and water called *brine.* The warm gaseous refrigerant becomes a liquid again when it is compressed by a pump and cooled by cold water running over the coil of pipes through which the refrigerant circulates. In the meantime very cold brine solution is circulated through pipes in an air-conditioning chamber. The air of the entire house is circulated through this chamber where it is not only cooled but also cleaned.

The cleaning is done by passing the air either through a moist glass wool filter, or through electric plates which attract dust particles. Much of the extra water vapor in the air is removed by condensation just as it is on the freezing unit of a kitchen refrigerator. Meanwhile in another coil, the refrigerant is compressed and cooled to a liquid to be used over again.

There are other smaller types of air-conditioning units available which will take care of the needs of a single room. There are also some systems so designed that both the heating and cooling of the air in a building can be accomplished by the one unit. The same unit also regulates the amount of water vapor that is to be added to or removed from the air, and it cleans the air at the same time (Fig. 137).

You can see that in order to obtain the most benefit from an air-conditioning system both in winter and summer, the windows of the house should be kept closed. Sometimes an extra window, called a storm window, is attached from the outside when cold weather is expected. The two panes of glass and the layer of air between them reduce the loss of heat and, therefore, help to maintain the inside temperature at a comfortable level.

YOUR OWN AIR CONDITIONING

You are convinced, no doubt, that air conditioning is expensive. But you may use some of the information you have gained in this chapter to air condition your home by simple means.

Does the air in your home dry out rapidly so that the humidity is low? A low humidity is known to cause irritation of the skin and the mucous membranes in the nose and throat. You can help increase the humidity by putting a pan of water on the radiator. Or you can place a number of thriving green plants in the windows. Green plants give off water from their leaves. The pots of earth also evaporate water into the air. Thus while you cannot regulate the moisture to a perfect relative humidity of 50 per cent, you can add some moisture to dry air by the methods suggested above.

Does your home get too hot or too cold because you cannot regulate the heat properly? If you use a fireplace or a stove, there isn't much you can do except to open and close windows when it is too hot or too cold. But if you have an oil or gas furnace you may have a thermostat. This should be set at a comfortable 68° F. if the relative humidity is approximately 50 per cent. In the wintertime you can help keep this temperature and save fuel by adding storm windows.

SHELTER AGAINST RAIN AND WIND

Primitive man lived in caves or in rude shelters built of logs and grass. Later, as man learned to control his environment, he changed these rude shelters, but he continued to use similar materials. As you know, most houses today are built of either wood or stone.

Wood may be used in shingles or boards covering the sides of the house and the roof. The stone may be fieldstone gathered from the fields, or stone cut by a stonemason. Or stonelike material may be manufactured from sand and other materials to form a concrete block. Ground stones of certain types may be used to form asbestos or cement shingles (Fig. 138), while ground-up stone and clay may be used to make certain types of brick. Whether we use wood or stone or brick we are using materials which with care are strong enough to withstand the pounding of rain and wind for a lifetime.

THE NEED FOR PAINT

Those people who build houses of wood generally paint the wood to preserve it and give it weather-resisting qualities. Wood has pores in it. In unpainted wood, these pores may fill with rain water. Fungi and bacteria, and wood-eating insects, thrive on wood that is wet. Wet wood rots easily.

Also, rain water freezes in the pores of wood. As water freezes, it expands in the pores and makes them larger. Eventually, the pores of the wood are enlarged enough so that rain actually seeps past the outer siding and wets the inner walls of the house. Here fungus and bacteria thrive and cause rot to appear.

Finally, wood absorbs water. Some woods like oak absorb water slowly. Others like pine or fir absorb water at a faster rate. When wood absorbs water, its fibers increase in length, and warping occurs.

Painting, therefore, prevents warping and rotting by closing the pores in wood. Paints contain linseed oil, which helps to form a protective coat when it dries. The linseed oil and lead in paint also furnish a smooth surface that allows rain drops to slide off instead of sticking on the wood to be

absorbed. Paint also contains substances which are poisonous to fungi, bacteria, and insects.

WATER, COLD, AND HEAT ON STONE

Have you ever seen a brownstone house which has been exposed to rain and cold and heat fifty years or more? Brownstone has a spongy surface full of tiny holes. Water enters during storms. Later as the weather turns colder, the water freezes; it expands in the surface cracks and splits the stone. In summer, the stone expands under the rays of the sun and contracts at night. Eventually, due to the effects of weather, *exfoliation* (ĕks fō′lĭ ā′shŭn) occurs; that is, the surface layers flake off. The same thing will happen to poor quality concrete. Even massive stones wear away in time; however, granite makes good building material because it will outlast generations of people. Probably you have seen pictures of the ruins of Rome or Athens. Only the stone parts of these famous buildings remain.

Other parts of a house besides the walls must withstand rain, cold, and heat. The roof, the steps, the windows, and the foundation all must bear their share. A foundation must be waterproof, or else the cellar will be damp. For sealing the foundation against ground water, pitch, a tarlike substance, is sometimes used. Pitch is impervious to water. Sometimes waterproofed building paper is used to wrap up the cellar of the house almost as you would a package. The edges of the paper are then sealed against the foundation and cellar walls with pitch. Another method, developed during World War II, consists of painting the walls and floor of the cellar with a special paint which forms a hard waterproof surface when it dries.

138 *Applying asphalt shingles to a roof. Why are asphalt shingles better than wood shingles?* (*Johns-Manville*)

A roof must withstand not only wind and rain and the weight of snow in the temperate zones, but also wind-blown sparks from the chimney. In some places, tile is used on roofs; in others, asbestos shingles. Both are better than wood shingles because they last longer and are fireproof.

SAFETY FROM FIRE

If it is important to protect home dwellers from conditions of changing weather, it is certainly as important to protect them from fires, which may spread because the construction is faulty. The Underwriters' Laboratory, The American Gas Association Testing Laboratories, and the United States Bureau of Standards have made many recommendations about home construction and repairs. But let's consider right now how protection from fire can be built into a house.

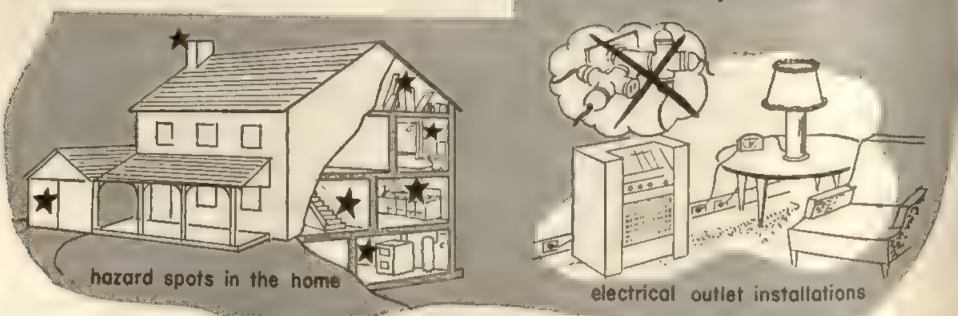
BUILT-IN FIRE PROTECTION

The walls of houses are usually built of studs, which are pieces of wood two inches by four inches placed vertically

12 inches to 16 inches apart. On the outer side of the studding the exterior wall material called "sheathing" is fastened. This kind of construction leaves an air space between the inside and the outside walls (Fig. 139). This is the space that may be filled with insulating material such as rock wool (Fig. 140). Poured concrete at each floor level (called fire stops) will have the advantage of slowing or stopping the spread of fire through these spaces in the walls (Fig. 139). Otherwise, if a fire starts in the basement, it may spread in these spaces and trap the tenants.

REDUCING FIRE HAZARDS

Strange as it may seem, many people burn down their houses in their efforts to keep warm. Of course, they do not intend to do so when they start fires, because fireplaces and furnaces are supposed to burn fuel safely. However, chimneys and flues may be defective, permitting sparks to reach the parts of the house that will burn. Sometimes people neglect to place a fire screen around the hearth and sparks reach wooden floors or rugs. These sparks often smolder for some time and then suddenly burst into flame.



139 *Where are the fire hazard spots in a frame house? What may be done to prevent the start or rapid spread of fire? Are there fire hazards in your home? (Adapted from "Hidden Hazards," published by The Insurance Company of North America, 1946)*

Sometimes furnaces and stoves are placed too close to walls that will burn when overheated. A sheet of metal under and around stoves will serve as a safeguard. Metals conduct heat away rapidly and also radiate and reflect it. This helps to prevent overheating of other nearby materials that might burst into flame.

Chemically treated wood reduces the fire hazard of fire by retarding the spread of flames. The use of a fire-retarding paint will also reduce the possibility of fires spreading rapidly.

SPONTANEOUS COMBUSTION

Sometimes fires start without apparent cause. Often such fires are the result of spontaneous combustion. In spontaneous combustion, the material suddenly bursts into flame. How does this happen? It may happen in barns where damp hay is stored, in coalbins where powdered coal is stored, or in closets or attics where oily rags are placed. The oil on the rags or the coal may combine slowly with oxygen in the air. This process is called oxidation, and oxidation produces heat. Since the heated air cannot escape from the coal or oily rags, their temperature is raised. Finally, the kindling temperature of the coal or oily rags is reached. Kindling temperature is that point at which the material bursts into flame. Carelessness in the storage of combustible materials causes much property damage and the loss of many lives every year (Fig. 141).

FIRE EXTINGUISHERS AT HOME

Even with the best of intentions and with the best of care, you may be unable to prevent an unexpected fire at home. To be safe, you and your family must be prepared to put out a fire quickly.

To start a fire, or to keep it burning, three things are needed. A fire needs fuel, oxygen, and heat. You will remember that burning is the combination of oxygen with a fuel (wood, coal, paper, or anything that will burn). Also, in order to start burning, the fuel needs to be heated to its kindling temperature. If we lower the temperature of the fuel below its kindling temperature as is done by throwing water on the fire, the fire is extinguished. Now that you know what is needed to maintain a fire, you can guess the principles underlying the extinguishing of fires. To extinguish a fire, we need only remove one of the things it needs to keep burning—fuel, oxygen, or some of the heat which keeps the fuel at its kindling temperature. All fire extinguishers work on the principle of removing one or more of these factors.

Most small fires can be extinguished by throwing water over them. The temperature of the fuel is immediately lowered below its kindling point. But

140 *This workman is placing a mineral (fireproof) insulating material between the beams in an attic floor. The insulation will help to keep the house cool in summer and warm in winter. (Johns-Manville)*

141
This is only one of the 340,000 homes that are destroyed or damaged by fire each year in the United States. (National Board of Fire Underwriters)

suppose an open pot containing some fat catches fire. The easiest way to extinguish it is to place a cover on it. Do you know why? First, the cover keeps out the oxygen needed for burning. Second, when most things burn (combine with oxygen) carbon dioxide is produced. The carbon dioxide which is produced by the burning fat is heavier than air. Therefore, it remains in the covered pot and blankets the fat, thus shutting out the oxygen.

FIRE EXTINGUISHERS AT SCHOOL

Sometimes you will see a pail of sand and an asbestos blanket in your science laboratory. Now you understand how they can be used to extinguish small fires. The sand smothers the fire by keeping oxygen from it. So does the blanket.

You will also see several types of fire extingishers in the laboratory or in the halls of the school. One of these may be a fire extinguisher which uses a vaporizing liquid. This kind of extinguisher works in a different way than do most extinguishers. It contains the substance carbon tetrachloride (tĕt′-rȧ klō′rīd). When carbon tetrachloride is sprayed on a fire, it cools the fuel below its kindling temperature. Its evaporation also produces carbon tetrachloride vapor, which smothers the fire because oxygen cannot get to the fuel. Other fire extinguishers work on a different principle which you can best learn by making a model.

MAKING A FIRE EXTINGUISHER

The fire extinguisher described below should be made under the supervision of your teacher.

Take a quart milk bottle and fit it

with a rubber stopper and glass nozzle. Fill it one-quarter full of water in which you have dissolved two tablespoons of sodium bicarbonate. Suspend a small bottle or vial of an acid like hydrochloric acid from the stopper. Be careful to use only dilute acid. Now stopper the bottle and use wire or cord to tie the stopper to the bottle.

When you turn the bottle over the acid and sodium bicarbonate will mix. Do this over a sink, of course. This mixture produces carbon dioxide which forces a spray of water through the nozzle. Thus a mixture of water and carbon dioxide is sprayed on the fire. The water lowers the temperature of the fuel below its kindling point and the carbon dioxide blankets the fire, keeping out the oxygen.

Some commercial fire extinguishers work on this principle. They are called soda-acid fire extinguishers. They contain water in which sodium bicarbonate (baking soda) is dissolved. The acid is in a bottle near the top of the extinguisher. When the fire extinguisher is turned over for use, the acid and soda are mixed to produce a spray of water and carbon dioxide. Some fire extinguishers also have a substance in them which produces a foam and carbon dioxide (Fig. 142). The foam helps blanket the fire and floats on the surface of burning oil. Foam-type extinguishers rather than water should be used to put out burning oil or gasoline fires.

There are also fire extinguishers which produce carbon dioxide only. Because carbon dioxide is heavier than air, you can actually pour carbon dioxide over a candle flame and extinguish it.

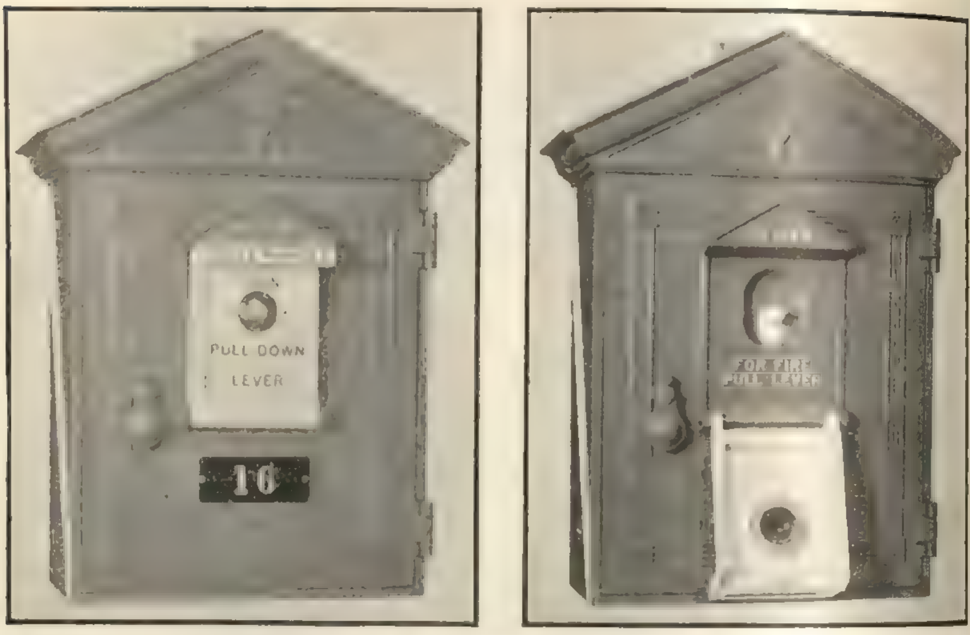
SAFE FROM FIRE

If you live in a private home, you should have at least two fire extinguishers. You should have a large one in the cellar. In the kitchen you should have a small hand fire extinguisher of the carbon dioxide or vaporizing liquid type. Of course, you may feel sure that no fire will start in your home. However, according to a recent survey by experts, a home is burning somewhere in America every minute of the day and night. A fire extinguisher in your home may help keep it off this list.

IN CASE OF FIRE

If your house or your neighbor's house does start to burn, the first thing to consider is how everyone in the house will escape. This should be accomplished according to a previously prepared plan just as in a fire drill at school. You may be sure your teacher knows two or more alternate routes for leading you out of the school in case the one your class usually takes becomes blocked during an emergency. Wherever you are—in school, at home, in a friend's

142 *This is a foam-type fire extinguisher. It spreads a blanket of foam over the burning material. Why is this a good extinguisher for oil fires? (American-La France Foamite Corp.)*



143 *A fire alarm box should never be opened except by a fireman. To send an alarm all you need to do is to pull down the lever on the outside. Then stay at the box until the fire engine arrives so you can direct the firemen to the fire. Inside the box is a loud bell to attract attention after the alarm has been sounded. There is also a telegraph key by which a second, third, or greater alarm may be sent. Do you know the location of the fire alarm box nearest to your home?* (The Gamewell Co.)

home, in a place of business, restaurant, theater, or other public place—always make a mental note of at least two exits.

When a fire starts you have to act quickly. If an escape route is open and you are alone, call for help and fight the flames if the blaze is tiny and if you have a good chance of preventing its spread. Never attempt to fight a fire single-handed if the flames have gained headway and are spreading rapidly or if there is much smoke. You may lose your life in the attempt. Firemen know how to fight fires. They should be called at once. Do you know the location of the nearest fire alarm box (Fig. 143)? Do you know how to operate it?

Knowing how to leave a burning building is also important. Heated air and the hot, poisonous gases resulting from the fire can outrace you and kill you before the flames reach you. As you leave a burning room close the door behind you. If the fire is in another part of the house do not leave the room you are in unless you are certain the air in the corridor is safe. Invite one of the members of your local fire department to demonstrate how to act in case of fire.

You spend a large part of your life in houses. It is reasonable to assume that you want to spend this time in comfort and safety. This chapter has given you only an introduction to the topic, "Healthful and Safe Housing." You can learn a great deal more by doing the activities at the end of this

chapter. You can do a great deal by applying what you have learned to keeping your own home safe and fit.

GOING FURTHER

1 *Sunlight on dyes.* Compare the effect of sunlight upon different types of dyes. You may test pieces of store-dyed cloth and you may dye pieces of white cloth, saving one piece in each case to be used for comparison at the end of the test. Exposures may be made for different lengths of time.

2 *Water absorption of cloth.* Wet equal-sized samples of various clothing materials and note the time it takes for each to become dry. Repeat the test, noting the amount of water each sample is able to absorb.

3 *Effects of weather on paints.* Secure several pieces of unpainted wood of about the same size. Paint all but one of them with various types of indoor and outdoor paints and varnishes. Expose these to the same weather conditions over a period of several months and then compare the condition of the surface with the unpainted sample.

4 *Labeling hazards.* Draw a scale diagram or floor plan of the house you live in. On the drawing, place a red cross where a hazard exists; place a black cross wherever it is not weatherproof; place a blue cross where ordinary repairs need to be made. You may put a circle around each of these crosses when the condition has been remedied.

5 *The amateur architect.* If a house is being constructed in your neighborhood, photograph it in each stage, showing how walls, floors, roof, etc., are constructed.

6 *A model hot-air heating system.* Make a model hot-air heating system, using tin cans and sheets of asbestos which your teacher may be able to obtain. A Bunsen burner, a candle, an electric bulb, or an alcohol lamp can serve as the source of heat.

7 *Words are ideas.* Can you use these words in sentences which will give their meaning? Use the glossary.

air conditioning	humidifier
brine	insulation
central heating	ventilation
dead air space	radiator
textile	refrigerant
exfoliation	storm windows
fiber	stud

8 *Put on your thinking cap.*

1. List the things you would look for in buying a good suit or overcoat. Explain why.

2. Why is it sometimes costly to follow fashion fads closely?

3. Find out what the people who live in them think about the advantages and disadvantages of prefabricated houses.

9 *Test yourself.* In your notebook, complete the following sentences with a correct word or phrase. Do not mark this book.

1. An open weave in clothing permits better ...... and therefore better ...... of perspiration.

2. Protection against the wind is provided by garments made of .... The warmest color is ....

3. The parts of a house most affected by weather changes are the ......, ..., ..., and ....

4. Tar and tar paper are often used to obtain protection from .... Good wall and roof insulation will keep a house ...... in summer and ...... in winter. For this purpose, mineral materials are best because they are .... Another insulating material is ....

5. As far back as 1912, it was discovered that the ideal indoor temperature for ordinary purposes is ......° F. when the humidity is between ...... per cent and ...... per cent.

6. The three main types of central heating systems are ......, ..., and .... In each case, the furnace may use as a fuel ......, ..., ..., or ....

7. Complete ...... includes the cooling of indoor air as well as controlling other factors.

8. For fire protection ...... should be built into the walls between the floors.

10 *Adding to your library.*

1. *The Pictorial Outline of Progress*, Metro Publications, New York 1936. Several pages of pictures are devoted to tracing various developments in housing and clothing through the ages. This material is excellent for reference, if you wish to study the evolution of inventions.

2. *Hidden Hazards*. This is a free pamphlet published by the Insurance Company of North America, 1600 Archer St., Philadelphia 1, Pa. It is "a guide to help you make your home safer through the selection of proper materials and proven methods of construction." The illustrations and writing are both excellent.

3. *Housing Practices—War and Prewar*, National Housing Agency, May 1945, from Superintendent of Documents, Washington, D.C. (15 cents). This is a review of design and construction, developments in materials and equipment, changes in construction methods, and building code problems.

4. *Home Heating*. This is a free pamphlet published by the Household Finance Corporation. It describes costs and details of construction and operation of nine types of indoor heating equipment.

5. *Judging Fabric Quality*, Farmer's Bulletin No. 1831, United States Department of Agriculture, 1939 (5 cents). This is an excellent, concise description of fabrics and fibers. It is as important as any booklet you can obtain.

6. *Consumer Goods* by Reich and Siegler, American Book Co., 1937. This comprehensive textbook has many chapters devoted to clothing and textiles. It also has some material on house furnishings and on materials used in the construction of houses.

UNIT FOUR

INVESTIGATING THE EARTH'S STOREHOUSE

Above: The famous atomic bomb explosion at Bikini. Below: A view through a periscope of the apparatus inside a "hot" cell, where radioactive substances useful in medical and other scientific research are being made. (U.S. Army)

Problem: How shall man use his knowledge of the atom?

An explosion in New Mexico

At 5:00 A.M., on July 16, 1945, a thunderstorm was passing over a lonely section of a desert in New Mexico. The rain was lessening. There seemed to be no life in the waste of land except the small desert animals that began to stir as light appeared in the eastern sky. At 5:15 A.M. the rain stopped and the light grew stronger. If you had been present, you could have seen a slender steel tower which supported a metal object at the very top. Only a few people knew that inside that object was a product of the greatest scientific search in history—a small amount of a substance called uranium 235.

Six miles away, behind a timber and earth shelter, men crouched over a panel of dials and instruments. Ten miles away, a group of scientists lay flat on the ground, their eyes protected by dark glasses.

At 5:29½ A.M. the sky was much lighter, and then at 5:30 A.M. an incredible and blinding explosion lit up the whole sky and made it brighter than the brightest daylight. A mountain range three miles away stood out in bold relief. Four hundred and fifty miles away, in Amarillo, Texas, the flash was seen.

After the gigantic flash came a terrific crashing roar and a heavy rush of air that knocked down two men who had stood up near the central station six miles away. An enormous surging cloud of dust boiled upward into the sky. The slender steel tower was turned into gases by the tremendous heat.

This explosion was the greatest ever created by man, and the most terrible. The effects of the explosion extended into the capitals of every nation; they affected every man and woman. The scientists who contributed to the first atomic explosion will take their places in history with the ancient men who first discovered fire, with the inventors of gunpowder, with those who discovered uses for steam and gasoline, and with those who produced light and power from electricity. These atomic scientists had proved that in the atom itself lay a great source of energy which could be released when the atom was split.

Perhaps your generation will see the energy of the atom harnessed for peace. Your generation may learn to deal with atomic energy as the previous generation learned to deal with electrical energy. In this unit, you will learn what you need to know about atoms, namely, what they are and how certain atoms may be split. You will see why atoms have been called the building blocks of our universe. You will see how greatly our civilization depends on the storehouse of chemicals in the earth's crust and how man improves Nature's storehouse.

CHAPTER 12

ATOMS— BUILDING BLOCKS OF THE UNIVERSE

About 2,400 years ago, there lived in Greece a philosopher named Democritus (dē mŏk′rĭ tŭs). He was one of the many original thinkers in the Greece of that time. He stated that everything—living as well as nonliving—was made up of tiny bits of matter. He reasoned this way: "Suppose I cut a piece of gold wire into two equal pieces. Then I divide one, and continue dividing each succeeding half-piece of wire. There must come a time when I can divide the gold no more, no matter what tool I use. I will have reached the smallest particle of gold that could possibly exist. Of course it would be too small to see." Democritus gave the name *atoms* to these tiny, invisible particles.

But Democritus in his thinking about atoms was dealing not only with gold. He was also dealing with everyday stuff—the stuff you see all around you every moment of your life. Scientists call this stuff *matter*. All things are made up of matter.

In this chapter, you will learn what matter is and how scientists since the time of Democritus have studied it. You will find that in their studies of matter scientists have discovered things which changed your way of living. Let us look into these discoveries.

MATTER— ALL AROUND YOU

You can test your scientific ability to observe by examining any object on your desk. It may be a book, an eraser, a ruler, or a pen. After looking at it carefully write down on a piece of paper everything you can think of that will really describe the object. This is not an easy task by any means. A trained scientist itemizes the properties of the materials under many headings such as: *color*, *size*, *shape*, *luster* (dull or shiny), *hardness*, *weight*, *solubility* (ability to dissolve in water), *combustibility* (ability to burn). Now go back to your list. What have you written for the properties of your object? Examine a different object, like a penny or another coin. Write down its properties. Now let's go further.

ARE THERE DIFFERENT KINDS OF MATTER?

If you examined your two objects carefully, you may have noticed they

were alike in some ways and different in others. But at least each had a definite size and shape and a definite weight. All matter that has definite size and shape and has weight is classed as a solid. "But," you say, "not all matter is solid." You are certainly right. Take a piece of ice, frozen water, a solid. It has a definite size and shape and has weight. Now put the piece of ice in a test tube and heat it. The size and shape of the ice change as it melts. What is the shape of the water? Continue heating. What happens to the boiling water?

By this simple experiment you have discovered several important facts. You have seen that water, a liquid, takes the shape of the container in which it is placed. You know it has weight because the test tube is heavier with water in it than it is when empty. You have seen that boiling water turns into a different kind of matter: steam, a gas. A gas spreads evenly through any container in which it is placed. That is why you get just as much air in one corner of a room as in another. That is why when you pump up your bicycle tire, you don't expect the air to remain in one part of the tire. A gas also has weight—a truck tire when inflated may weigh as much as 25 pounds more than when it is flat.

You know now that matter exists in three forms by which it can be identified: *solid*, *liquid*, and *gas*.

1. A solid has a definite size and shape and has weight.

2. A liquid takes the shape of its container and has weight.

3. A gas spreads evenly through its container and has weight.

CLASSIFYING MATTER

Can you think of anything in this world that is not a solid, a liquid, or a gas? What is rock? wood? air? water? even the sun and stars?

Make a list of familiar things you see or use at home, on the way to school, or at play. Now let's see if you can classify each one according to its properties. Suppose you were to examine a pebble.

Color	brown
Size	small
Shape	round
Luster	dull
Hardness	hard
Weight	10.1 grams
Solubility	none
Does it burn?	no
Kind of matter	solid

Try the same for a piece of glass, a can, a penny, and water.

You may find that you have to think carefully about some of the things in your list. While you are doing so, you are probably wondering why everything is either a solid, a liquid, or a gas. Why does ice, for example, change to water and then to steam when you heat it?

ELEMENTS AND MOLECULES

In order to discover why substances change into different states of matter, solid to liquid, or liquid to gas, we must look further into the make-up of these substances. Suppose you were to divide a quantity of water into the smallest portions which would still be water. What would you have?

MOLECULES

A molecule is the smallest part of any substance that has the characteristics or properties of that substance. Thus the smallest particle of rubber that will stretch is a molecule of rubber. The smallest particle of salt that acts

like salt is a molecule of salt. The smallest particle of carbon dioxide that will fizz from your bottle of ginger ale is a molecule of carbon dioxide. Molecules cannot be seen with the naked eye or even with ordinary microscopes. However, some large molecules have been seen through the powerful electron microscope.

MOVING MOLECULES

Now let's see why matter may be changed from a solid to a liquid and from a liquid to a gas. In most solids molecules are more closely packed than in liquids like water or in gases like steam, or those in air. In liquids the molecules are more closely packed than in gases (Fig. 144). However, even in solids the molecules are not stationary. Scientists have found that they are constantly moving or vibrating.

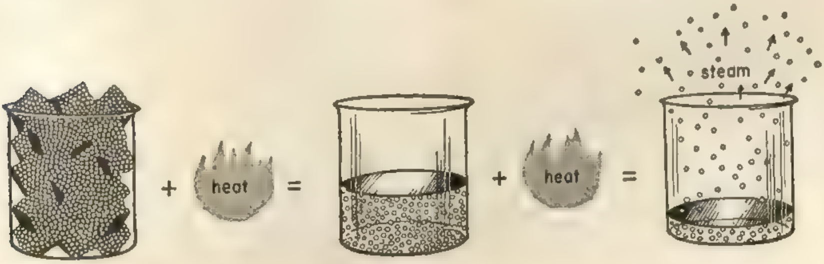
Here is some indication of this vibration. Have you ever hit the end of a nail a number of times while holding on to the other end? Try it. Use an ordinary hammer and hit smartly. The heat you feel is due to the increased vibration given to the molecules by striking the nail with a hammer. Likewise, if you had a sensitive instrument to measure the nail after hitting it, you would find that it had grown just a bit longer. In other words, you heated the nail—its molecules vibrated faster—it became longer. Can you see why there are gaps left between railroad rails? Between girders in steel bridges?

Increasing the vibration of the molecules may cause a change in the state of a substance. Ice when heated becomes a liquid (water). Molecules of water when heated spread farther and farther apart until they leave the liquid as steam (a gas) as shown in Fig. 144.

Thus it is heat that causes a substance to change from one form into another. Solids when heated enough will change into liquids. All liquids when heated enough will change into gases. To take another example, steel, a solid, when heated enough will melt into a liquid. Heated still further, it will turn into gas. The process works in the opposite direction too. Air, a mixture of gases, will become a liquid when cooled far below zero. When cooled still further, air becomes a solid like ice. The changes in the state of matter are called *physical changes*. In a physical change, the molecules of a substance remain the same.

Now you can understand why everything around you is a solid, a liquid, or a gas. The form or state of a substance depends upon how hot it is. The degree of heat can be measured by taking its

144 *By increasing the motion of molecules heat changes ice (below left) into hot water (center), then into steam (right). Thus, heat can change a solid into a liquid and finally into a gas.*



145 *A ninth grade student is about ready to collect oxygen in the test tube he is holding. (High School Science Department, Brookline, Massachusetts.)*

temperature. The temperature of a substance is really a measure of the speed with which its molecules vibrate.

WORKING WITH MOLECULES

Molecules of some substances can be broken up by heating them to increase the rate at which the molecules vibrate. Thus mercuric oxide, composed of mercury and oxygen, will break up into mercury and oxygen when heated. You can do this in your school laboratory (p. 227).

Molecules can also be broken down by an electric current. Let's see what happens to water molecules when an electric current passes through them.

Your school laboratory probably has a piece of apparatus like that in Figs. 145 and 146. Fill the apparatus with water to which has been added a little sulfuric acid. Connect the apparatus to two to four dry cells.

Notice the bubbles of gas rising in each tube. In one of the tubes, however, the level of water is falling twice as fast as in the other (Fig. 146). A gas is collecting in each tube as the energy of the electric current breaks up the molecules of water. The pressure of the gases forces water out of the tubes. What gases are these? Let's test them.

Hold a test tube over the tube which has more gas. Open the end of the tube. The gas rushes upward into the test tube. Test this gas with a burning splint of wood. A small explosion takes place; you hear a small "pop." Hydrogen explodes when it is mixed with air and ignited. Since you know that water

contains hydrogen, you conclude that the tube with the lower water level contained hydrogen (Fig. 146).

Now collect the gas in the other tube and test it with a glowing splint of wood. The splint bursts into flame. Pure oxygen supports burning much better than air, which contains only 20 per cent oxygen. Since you know that water contains oxygen, you conclude that the test tube with the higher water level contained oxygen.

Here is what you might further conclude:

1. The volume of the hydrogen formed from breaking up water molecules is twice the volume of the oxygen formed. Your reason is that the water level in the hydrogen tube fell twice as far in the same time as the level in the oxygen tube. Therefore, water contains twice as much hydrogen by volume as oxygen.

2. Since the smallest particle of water is a molecule, a molecule of water contains twice as much hydrogen as oxygen.

3. Scientists know that molecules are made up of atoms. (An atom is the smallest part of an element—like hydrogen or oxygen—that has the properties of the element.) Therefore you would finally conclude that each molecule of water must contain at least two atoms of hydrogen and one atom of oxygen. Thus when an electric current is passed through water, each molecule breaks up as follows:

1 molecule of water → 2 atoms of hydrogen + 1 atom of oxygen

1 molecule of water → 2 atoms of hydrogen + 1 atom of oxygen

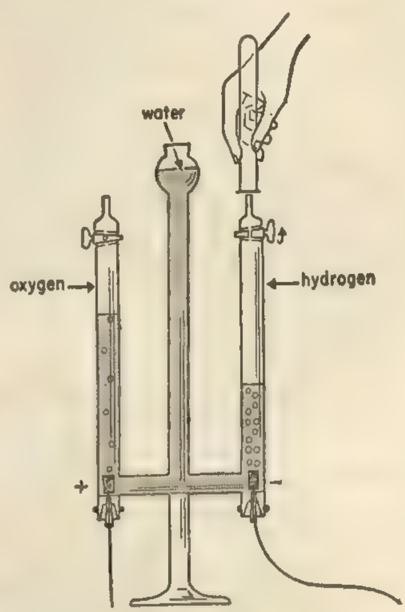
and so on until all the water is used up.

You can now see why water is called H_2O. Writing H_2O is the simplest way to show that there are two hydrogen atoms and one oxygen atom in a molecule of water.

And when we change molecules of water or any other substance into their separate elements, or unite elements to form molecules, the process is called a *chemical change*. This is different from a physical change, in which just a change in the appearance of the material is made, like tearing a piece of paper, or changing ice to water, or water to steam.

COMPOUNDS AND ELEMENTS

An element is a substance that cannot be divided into any other substance by ordinary means. An element can be combined with other elements to make compounds. An element is made up of its own kinds of atoms.



146 *An electric current decomposes water (to which a little acid has been added) into two gases, hydrogen and oxygen. How does the volume of hydrogen gas produced compare with that of oxygen?*

Chemists know that when certain elements join together, the substance formed is entirely different in appearance and properties from the elements making up the substance. The substance formed consists of two or more kinds of atoms and is called a *compound*. Most of the materials you use or see every day are compounds. For example, common table salt consists of the elements sodium and chlorine. Sodium is a metal that reacts vigorously with water. Chlorine is a greenish-yellow gas that is extremely poisonous if breathed in moderate quantities. But table salt, a compound, does not react vigorously with the moisture on your tongue, nor does it give off a poisonous greenish-yellow gas.

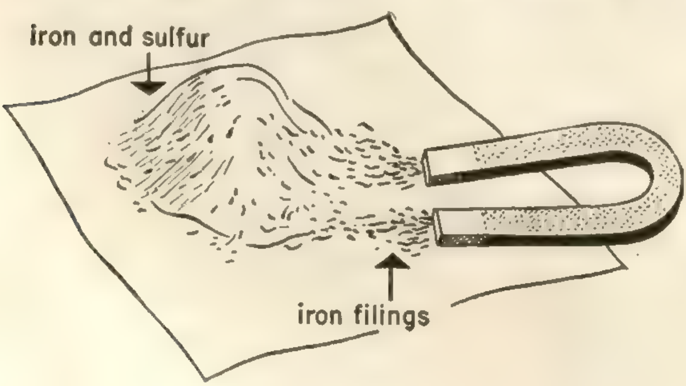
Sugar is a compound composed of carbon, hydrogen, and oxygen. None of these elements, tasted or breathed separately or together, would be sugar. Likewise, the water you drink is composed of two gases, hydrogen and oxygen, as you have seen. Would both gases breathed together satisfy your thirst?

Clearly some change takes place when elements form compounds. This change produces a compound very different from the elements that are in it.

MIXTURES AND COMPOUNDS

Place a teaspoonful of powdered sulfur and about two-thirds of a teaspoonful of iron filings on a piece of paper. Mix the iron filings and the yellow sulfur thoroughly. You will find that when you hold a magnet over the mixture some of the iron filings are attracted to the magnet. The yellow sulfur is not. Two or more substances in a mixture can often be separated one from the other (Fig. 147). What is the difference between a mixture and a compound? The substances in a mixture have not combined with each other to form a new substance. No chemical change takes place in the substances in a mixture. No new molecules are formed. But a compound is a new substance different from the substances from which it is made.

You can make a compound. Place the mixture of iron filings and sulfur in a test tube and heat strongly over a Bunsen burner. You will notice that the sulfur melts and then the mixture glows. Remove the tube from the flame, and after the tube has cooled, break it open by tapping the lower end sharply with a hammer. Now you will note that the substance inside the tube no longer resembles either sulfur or the fine iron filings. When you hold the magnet over the substance, are iron filings attracted to the magnet? You no longer have a mixture of iron and sulfur but instead a compound made up of iron and sulfur. It is called iron sulfide. It differs from the mixture of



147
A mixture of iron filings and sulfur (and a magnet). How does the iron get separated from the sulfur?

iron and sulfur in that these two elements are now combined chemically into a new substance.

Mixtures occur everywhere. You have learned that few of the elements exist by themselves in nature the way gold does. Usually they are combined with other elements. Similarly most compounds occur in nature mixed with other compounds.

Do you remember your study of rocks? You will then recall that many rocks were mixtures of materials of different kinds (p. 98). The water you drink is not absolutely pure; it contains small amounts of the substances found in the earth mixed with it. Sea water contains larger amounts of these substances than does fresh water, so that it is not healthful to drink it. Even the air you breathe is a mixture of nitrogen, oxygen, carbon dioxide, water vapor, and other gases. So it is that most solids, liquids, and gases making up the earth are composed of mixtures of compounds or elements.

BUILDING UP THE UNIVERSE

The entire earth—the entire universe—is made up of elements, compounds, or mixtures of elements and compounds. You cannot name anything that is not made up in this way. At this point you might summarize your knowledge by the following diagram. (The arrow should be read to mean "consist of")

earth and universe	→	elements and compounds or their mixtures	→	molecules made up of atoms

Or reading the diagram backwards, atoms make up molecules. Molecules make up compounds. Compounds, elements, or their mixtures are the solids, liquids, or gases that make up the earth and universe.

How many elements have been discovered by the research of scientists? Before 1940, we could say that we knew of 92 elements occurring on earth.

148 *Madame Curie, discoverer of radium, started scientists on the trail of other radioactive elements.* (*Science Service*)

But as work on atomic energy continued, scientists actually made four new elements.[1] Later you will learn how this great discovery, a method for making new elements, came about. Right now it is enough to know that man can make new elements and that he has actually made four of them.

These four new elements are called *neptunium* (nĕp tū′nĭ ŭm), *plutonium* (plōō tō′nĭ ŭm), *curium* (kū′rĭ ŭm), and *americium* (ăm′ĕr ĭsh′ĭŭm). The first, you can see, is named after the planet Neptune and the second after the planet Pluto. The third is named for Madame Curie, the famous Polish scientist (Fig. 148). The fourth, for America.

[1] Since the first printing of this text two more elements, berkelium and californium (numbers 97 and 98), have been made. Now there are six elements that man has made.

The evidence to date indicates that there are 96 elements. All the materials we know, compounds as well as mixtures, are made up of these 96 elements. These elements are further subdivided into the different kinds of atoms of which all matter is made.

ATOMS INTO SMALLER PARTICLES

You remember Democritus' idea of an atom—that the smallest particle of a substance is an atom. It was not until over 2,300 years after Democritus died that any extensive thought was given to atoms.

DALTON AND HIS ATOMS

In the nineteenth century, a great English scientist, John Dalton, published his atomic theory. This is what he said:

1. Atoms are exceedingly small.

2. Atoms of the same element weigh the same but are different in weight from atoms of any other element.

3. Atoms of one element can combine with atoms of another element to form new substances.

It is true that these statements seem very simple. Yet Dalton was the first scientist to speak of the weight of atoms. But how can you weigh an atom if you can't see it, even with a powerful microscope? Let's figure this out as Dalton may have done.

WEIGHING ATOMS

Gases like hydrogen are stored for commercial use in large metal cylinders. Suppose you released hydrogen from such a cylinder into a small tank whose size you knew exactly. Suppose you kept on until the gas in the smaller tank weighed exactly .09 grams (28.4 grams equal 1 ounce). Now suppose you released oxygen into another tank of exactly the same volume, shape, and weight. You want to get the same number of molecules of oxygen in one tank as you have of hydrogen in the other. How can you tell when you have the same number?

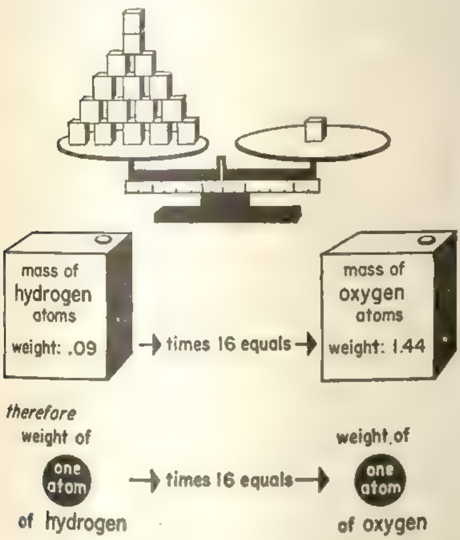
It is known that *any two tanks of the same volume will contain exactly the same number of molecules of any gas if pressure and temperature are the same.* Of course, if the temperature were lower, the molecules would move more slowly and require less space. More of them could then occupy a given tank. If the pressure were higher, more molecules could be squeezed into a tank. You have seen air forced into tires under pressure and you have noticed how much air can be forced in before the tires are inflated. You have seen the service station attendant measure the pressure of air in your tires.

You would measure the pressure in your tanks of hydrogen and oxygen in the same way. When the pressure reached the same point in the two tanks, you would weigh them. You know that the hydrogen in our special tank weighs .09 grams. You would find the oxygen weighs 1.44 grams. Simple arithmetic shows that 1.44 is exactly 16 times .09.

Since each tank contains the same number of molecules, you would conclude that a molecule of oxygen weighs 16 times as much as a molecule of hydrogen. Since each molecule of oxygen and hydrogen consists of two atoms, then one atom of oxygen weighs 16 times as much as one atom of hydrogen (Fig. 149).

This is certainly a clever way to get a relationship between the weights of the hydrogen and oxygen atoms. Of course, you have not really weighed them. All you have done is to find out how much heavier or how much lighter

one atom is than the other. John Dalton found that one atom of oxygen is 16 times heavier than one atom of hydrogen. That is what we shall mean when we say that the atomic weight of oxygen is 16 and the atomic weight of hydrogen is 1. When we speak later of uranium 238 or carbon 14, we shall mean that atoms of those elements are respectively 238 and 14 times as heavy as a hydrogen atom. We shall use these numbers to mean the weights of the atoms of these elements. When we speak of *atomic weight*, we shall be referring to the weight of one atom of an element.



149 *The oxygen in the tank is 16 times heavier than the hydrogen in a similar tank. Since there are the same number of atoms in each tank, it follows that one atom of oxygen is 16 times heavier than one atom of hydrogen.*

DISSECTING THE ATOM

Still Dalton had not gone much further than Democritus. Their idea of atoms was the same. Both men thought atoms were like microscopic marbles (Fig. 150).

In later years, scientists made more rapid strides. In 1898 came the discovery of radium by Madame Curie. A few years later, it was discovered that atoms of radium really exploded. And as they exploded, they produced powerful effects. They threw off rays that went through flesh and even metal. One of these rays, it was discovered, was made of tiny particles of matter called *electrons* (ê lĕk′trŏnz).

You can well imagine what this last discovery did to the idea that atoms consist of tiny, solid particles like microscopic marbles. Since an atom of radium throws off electrons, particles of matter smaller than an atom, there must be electrons in atoms!

But surprises were not over. Scientists knew now what to look for, and they found that atoms of other elements heavier than radium—yes, even uranium—had been exploding since the beginning of time. It was necessary to give a name to the strange kind of activity these elements possessed. Scientists call it *radioactivity.* From a study of radioactive elements, scientists finally came to have a new and different idea of the atom.

FINDING THE NUCLEUS

Ernest Rutherford (Fig. 151), another English scientist, took up the search. He held the hypothesis, as did Niels Bohr (Fig. 151), a Danish scientist, that an atom is like a very small solar system. They supposed that the nucleus (center) is like the sun, and that the electrons like the planets move about the nucleus (Fig. 35).

This hypothesis, a good scientific guess, was based on a few known facts, but not many facts were known. Would the hypothesis fit new facts discovered later? It was important to get new facts to check the value and usefulness of the hypothesis. Rutherford thought of the

brilliant idea of using radium as a gun in hunting for more facts about the atom (Fig. 152).

When an atom of radium explodes, certain other particles are produced along with the electrons. These particles, much heavier than electrons, are exactly the weight of atoms of a gas called helium. It was these helium particles that Rutherford thought of as radium bullets. But they travel 20,000 times faster than the fastest bullets from a machine gun! How could he trace their paths?

Nowadays scientists use an instrument called a Wilson *cloud chamber*. This is how it works. Have you ever seen sky writing? The movements of the airplanes are traced by a cloud of smoky material. If you could not see the airplane, you would still know it was there by the path it had traced. Similarly radium bullets trace a path in the moist air of the cloud chamber (Fig. 153). Ruther-

150 *Steps in the progress of atomic knowledge from Democritus to you. Which is the most recent idea of the atom?*

151 *The researches of the Englishman, Sir Ernest Rutherford and the Dane, Niels Bohr, showed us much about the structure of the atom. (Both, Science Service)*

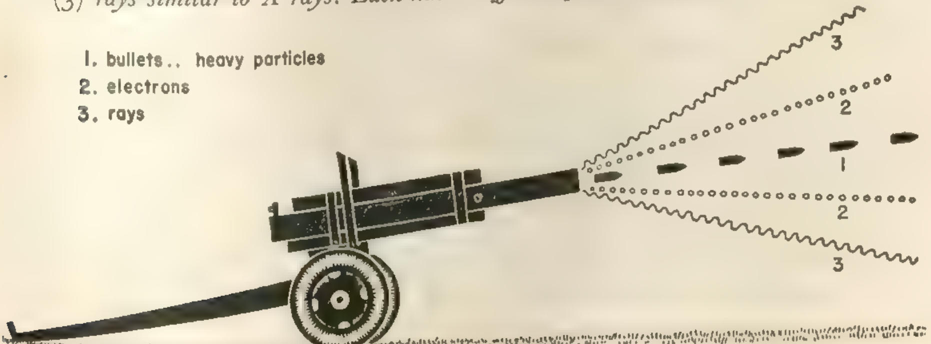
ford may have used the cloud chamber in his experiments or he may have used other methods too complex to be described here. In any event Rutherford could detect the movements of his invisible radium bullets.

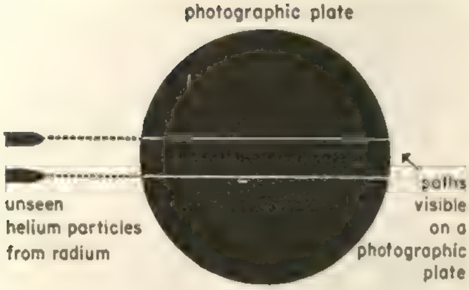
Then Rutherford began to work. He took some tin foil and placed it in the path of these radium "bullets." If one of these bullets hit part of an atom in the tin foil, the path of the bullet would be changed—much as a real bullet glances off a hard object it hits. If the bullet didn't hit part of an atom, its path would not be changed.

To Rutherford's surprise, most of the radium bullets he used passed through the tin foil as though the tin foil were not there. If a cloud chamber were used, the path of one of the helium particles would appear to shoot off at a sharp angle from the tin foil, showing that it had hit something and bounced off (Fig. 154).

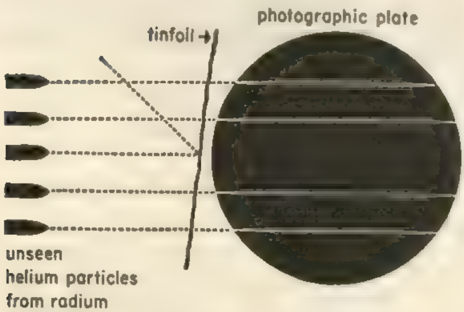
From his work Rutherford had evidence that his former idea was correct:

152 *Exploded radium atoms throw out (1) heavy particles, (2) streams of electrons, and (3) rays similar to X rays. Each has a different penetrating power.*





153 *The paths of unseen helium particles can be photographed. Note how straight the paths are.*



154 *When the nucleus of an atom of tin is hit, the path of the radium bullet is changed. When this happens, this path cannot be seen on the photographic plate.*

An atom is composed of a tiny center, or nucleus, with electrons moving about it much as our planets move about the sun. Most of the radium bullets passed right through the tin foil because they went right through the spaces between the nucleus and electrons of the tin atoms.

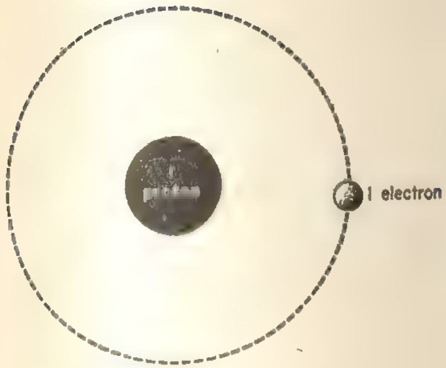
Imagine that it was something like this: Suppose an atom of tin could be enlarged to fill your school playground. The nucleus of the atom would be as small as a grain of wheat. Standing off to one side of the playground, how many times could you hit the grain of wheat with an air rifle? Once in a thousand shots? A hundred thousand shots? This will give you an idea of the difficulty of hitting the nucleus of an atom. Remember, however, that under actual conditions the radium bullets used are even smaller than the nucleus of the atoms against which they are fired.

Thus Rutherford concluded that, small as it is, an atom is mostly empty space, but the nucleus is its most important part. It is now known that if the nucleus of an atom of iron, for example, could be enlarged to the size of an orange, the electrons that move around it would move in circles 45 miles in diameter!

EXPLORING THE NUCLEUS

Meanwhile, many other scientists were working to discover the nature of the atom. They discovered that the nucleus of an atom contains particles of matter, which were named *protons* (prō′tŏnz). They reasoned that the lightest element known—hydrogen—would have the smallest number of protons in its nucleus and the smallest number of electrons outside. The hydrogen atom is made up of one proton and one electron. Now you see how easy it is to diagram an atom of hydrogen (Fig. 155). Of course, this isn't the way an atom of hydrogen really looks. We really don't know how one looks, nor how atoms of elements heavier than hydrogen look. This is just a simple way of diagraming an atom to help you picture it in your mind.

In 1932, James Chadwick, who followed Rutherford's experiments, discovered another particle in the nucleus of the atom. He called it a *neutron* (nū′trŏn). It weighs almost the same as a proton. Each neutron and proton in the nucleus of an atom is 1,840 times heavier than an electron outside.



155 *An atom of hydrogen consists of one electron rotating about one proton (in the nucleus). Remember that these are not actual sizes.*

Today scientists know that nearly the entire weight of the atom is in the tiny nucleus.

THE ATOM TODAY

Here is the atom as we know it today, so small that one can hardly picture its size. It would take 250,000,000 atoms of hydrogen placed side by side to make a line one inch long. No one has ever seen an atom—not even with the electron microscope. But the unending research of modern science has shown what an atom contains. To be able to picture an atom of hydrogen, as you have done with the help of this chapter, is an achievement that scientists one hundred years ago would have envied. You now have a good idea of what atoms contain. You know what is meant by the statement that atoms are the building blocks of the universe. We may summarize our ideas in the following statement. Again read the arrow to mean "consist of."

Whether you look at your clothing, your pencil, the chocolate you eat, or your home, you are looking at combinations of atoms. They are either in the form of elements, or compounds, or mixtures of elements and compounds. Look up at the moon, at the planets, at the sun, at the stars. They too are composed of atoms, elements, and compounds. The atom, truly, is the building block of the universe.

GOING FURTHER

1 *Heating metal.* Heat a piece of copper wire in a low gas flame for two minutes. Examine the coating on the wire when it cools. What color is it? Is it different from the copper you heated? Many metals when heated in air combine with the oxygen of the air. What would you call the black coating (p. 220)?

2 *Breaking up a compound.* Fill a test tube one-third full of mercuric oxide. Insert a stopper and delivery tube. Heat the test tube in a strong flame for five minutes. Collect the gas coming from the mercuric oxide into an empty test tube. Test the gas with a glowing splint. Is it the same gas you tested in the breaking up of water (p. 219)? Now examine the sides of the heated test tube. Compare what you see there with the appearance of mercury in the bulb of a thermometer. What do you conclude as to the elements that compose mercuric oxide?

3 *A model of hydrogen.* Make a model of an atom of hydrogen by taking a soft rubber ball for the nucleus. Mold a small ball of plastic clay on the end of a wire and insert the other end of the wire into the rubber ball. The small ball of plastic clay represents one electron. Now hang up your model as a display in class.

earth and the universe → solids, liquids, gases → elements, compounds or their mixtures → atoms (of elements) → protons and neutrons (in the nucleus) and outer electrons

4 *Words are ideas.* Can you use these words in a sentence which will give their meaning? Use the glossary where necessary.

matter	mixture	atomic weight
gas	combustibility	molecule
liquid	solubility	cloud chamber
solid	radium	nucleus
atom	radioactivity	proton
element	properties of	neutron
compound	matter	electron

5 *Put on your thinking cap.*

1. In a long steel bridge there are carefully calculated spaces left where the steel girders join the ends of the span. Why?

2. The formula for water is H_2O. What does this mean?

3. How did the discovery of radium help scientists to understand the atom?

6 *Test yourself.* In your notebook complete the following sentences with a word or phrase. Do not mark this book.

1. All matter consists of solids, ..., and ....

2. Molecules are made up of ...... or more elements. The molecules of compounds are made up of two or more different ......

3. Molecular vibration is increased by increasing the ....

4. The ...... weight of oxygen is 16 because an atom of oxygen is 16 times heavier than an atom of hydrogen.

5. The chemist's formula for water is ...... because water contains twice as many atoms of ...... as ....

6. The discovery of radium showed scientists that there are ...... in atoms.

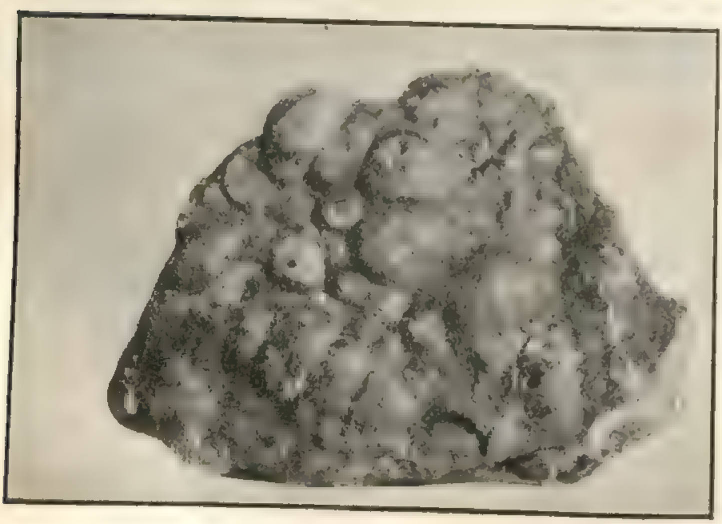
7. An atom consists of a tiny ...... like a sun with ...... like planets going around it.

8. The atomic nucleus contains ...... and neutrons.

9. Most of the ...... of the atom is in the nucleus.

10. Important work on the nucleus of the atom was done by the scientists ...... and ....

7 *Adding to your library.* You ought to read *Young People's Book of Atomic Energy* by Robert D. Potter, McBride and Co., 1947. This is a well-written story of the fundamental particles of which all things on this earth are composed. There is also a good explanation of atomic energy.



156

Sample of pitchblende ore from Great Bear Lake, Canada. (Bureau of Mines, Ottawa, Canada)

CHAPTER 13

SPLITTING THE ATOM

Would you have thought the Manhattan District referred to the greatest secret project of World War II? It sounds like a place where many New Yorkers live and work. You know now that Manhattan District meant one of the greatest undertakings of the war. You know it meant a race with German scientists working to build the most destructive weapon of all time.

This is the story of the Manhattan District. It is the story of scientists who, knowing what the atom contains, brought all their knowledge to bear upon splitting it. Theirs is a story of extreme difficulties but final success. It also suggests what the future may bring if atomic energy is used for peace and not for war. Now let us trace one of the greatest adventures of all times!

THE SECRET OF URANIUM

Uranium is one of the most important elements occurring naturally on the face of the earth. It is never found lying around loose like gold. It is often found combined with other elements and compounds in a dark, earthy mixture called pitchblende (Fig. 156). One of the richest deposits of pitchblende in the world is found at Great Bear Lake near the Arctic Circle in Canada. No matter where the pitchblende comes from, whether from Canada, Austria, the Belgian Congo, Madagascar, or Russia, the uranium derived from it always contains just two kinds of uranium in exactly the same proportions. Uranium 238 makes up 99.3 per cent of the total and uranium 235 makes up the other 0.7 per cent. This is to say, in every 140 pounds of uranium there is one pound of the lighter uranium 235.

Scientists have found that uranium as well as radium is radioactive; that is, it gives off rays like radium. They also have found that it is the lighter uranium 235 that causes most of this radioactivity, although the heavier uranium 238 is also radioactive. About 1940 uranium came to be considered a highly valuable substance and scientists all over the world began to study its properties. One of the instruments they used in this study is the cyclotron (sī′klō trŏn).

THE CYCLOTRON

The discovery of atomic energy called for the most extraordinary ex-

4 *Words are ideas.* Can you use these words in a sentence which will give their meaning? Use the glossary where necessary.

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liquid	solubility	cloud chamber
solid	radium	nucleus
atom	radioactivity	proton
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compound	matter	electron

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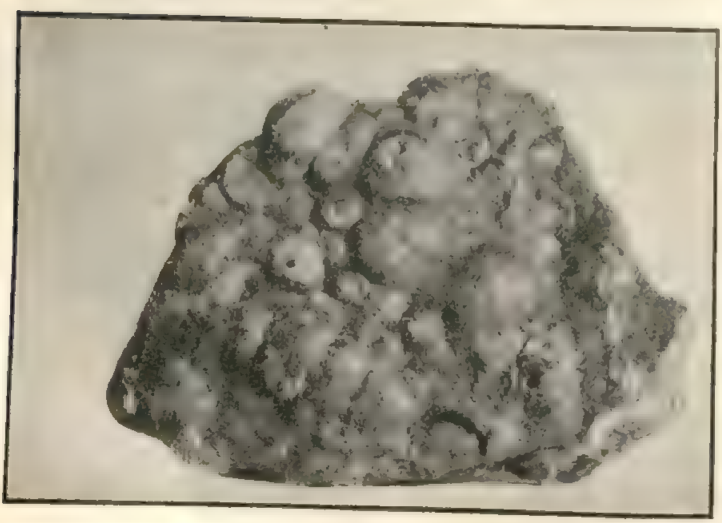

156
Sample of pitchblende ore from Great Bear Lake, Canada. (Bureau of Mines, Ottawa, Canada)

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THE CYCLOTRON

The discovery of atomic energy called for the most extraordinary ex-

ertions of man's inventive genius. In Fig. 26 you see a cyclotron, one of the so-called atom smashers. This machine, weighing hundreds of tons, consists mainly of a huge electromagnet, in which electricity is responsible for the magnetism.

One of the most important parts of the cyclotron is a hollow, divided copper disk over 60 inches in diameter. This disk, separated into halves about 2 inches high, has a 2-inch gap between the halves.

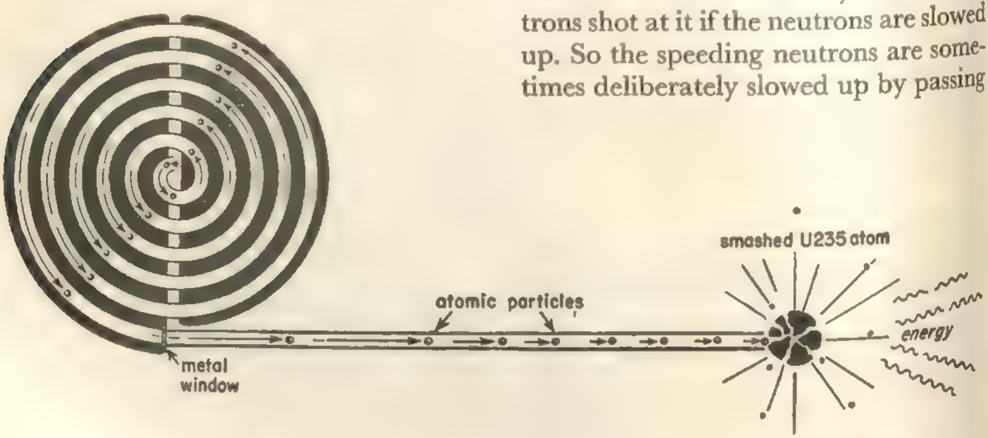
Because the hollow half-disks are shaped like D's, they are called *dees*. The dees are located between the poles of the powerful electromagnet.

Now here is how the cyclotron works. Suppose a rabbit were placed in the exact center of a spiral track and ran one complete revolution in the small spiral in one second. Then some force made him run the next spiral and the next in the same time. Since the spirals increase in diameter, pretty soon he is whizzing along at a speed beyond imagination. This is exactly what happens in the cyclotron. Instead of a rabbit, tiny particles, each consisting of an atomic nucleus containing a proton and a neutron, are shot into the center of the dees. There they are acted on by such powerful electrical and magnetic forces, now pulling the particles this way, now another, that their speed as they spiral along is raised to enormous heights. At the peak speed the particles are shot through a tiny metallic "window" at the end of the spirals (Fig. 157).

CHANGING ATOMS

The nucleus of an atom that is hit by these atomic bullets does strange things. It may absorb a neutron or it may absorb a proton. If the bombarded atom absorbs a neutron, it becomes heavier because the neutron's weight is added. If the bombarded atom absorbs a proton, its weight also changes but it becomes an entirely new substance. As early as 1919 Rutherford produced oxygen by bombarding nitrogen atoms. Radioactive phosphorus is made by bombarding sulfur in the plants at Oak Ridge. Even gold has been made from other elements by bombarding their nuclei.

It has also been found that the nucleus of an atom can easily absorb neutrons shot at it if the neutrons are slowed up. So the speeding neutrons are sometimes deliberately slowed up by passing



157 *Atomic particles from a cyclotron split atoms of uranium 235, releasing energy. The two dark D-shaped parts in back of the spiral represent the dees in which the atomic particles are speeded up.*

them through carbon before allowing them to hit the real target, the nucleus of an atom.

The cyclotron is called a particle accelerator because it increases the speed of particles of atoms. Other machines like the betatron (bā′tȧ trŏn) and the synchrotron (sĭng′krȯ trŏn) increase the speed of atomic particles even further. With these new high-speed machines scientists expect to learn more of the nature of the atom, more about treatment of cancer, more about how the elements and compounds of our world are put together.

WHAT IS ATOMIC FISSION?

Two scientists, Dr. O. R. Frisch and Dr. Lise Meitner, were among the first to note the effects of bombarding atoms of uranium with neutrons. The work was originally done by German scientists, of whom Dr. Meitner was one. They discovered that an atom of uranium behaved as no atom had ever behaved before. Instead of just changing its weight slightly, it split into several pieces (Fig. 157). These pieces together weighed a little less than the original atom of uranium. Since weight was lost, it was apparent that a small bit of uranium must have been transformed into energy. Calculations proved that if all the atoms in a pound of uranium 235 were made to split, or to undergo *fission*, as the process came to be known, as much energy would be released as in burning five million pounds of coal (Fig. 158).

The two scientists communicated their findings to Dr. Niels Bohr, the great Danish scientist who was Dr. Frisch's father-in-law. Dr. Bohr immediately made arrangements to come to the United States. He arrived in New York on January 16, 1939, and the stage was set for further work.

158 *This chart dramatizes what the energy released by splitting all the atoms in just one pound of uranium 235 could do. Read from the top down.*

THE MANHATTAN DISTRICT

Together with Dr. Enrico Fermi (Fig. 159), an Italian scientist working at Columbia University, Dr. John Dunning, Dr. Harold Urey of Columbia, and many other scientists, Dr. Bohr continued the research in uranium fission. This is what these scientists found: When an atom of uranium 235 was hit by slowed-up neutrons, it broke

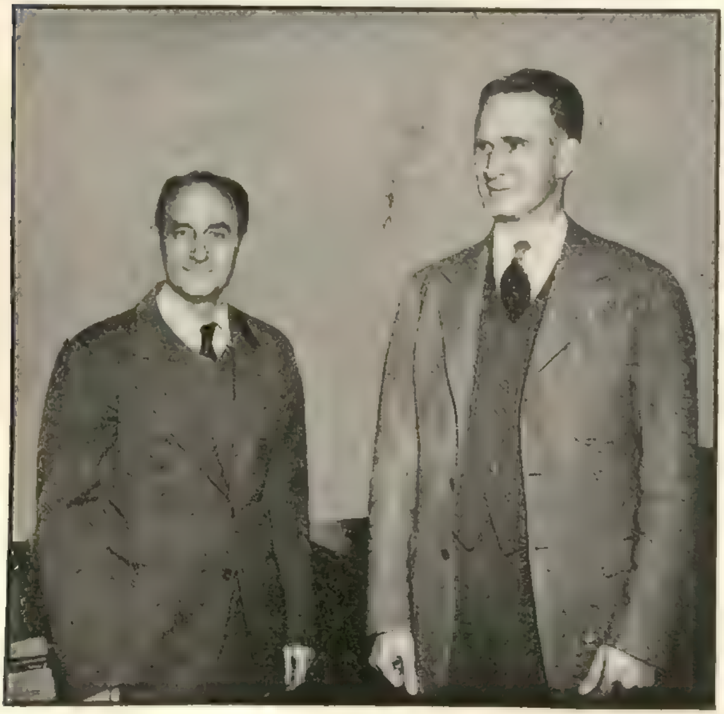
into several parts, but it also produced more neutrons. These neutrons, in their turn, hit other atoms of uranium 235 and broke them up—and more neutrons were produced. As each atom broke up, a part of the atom turned into energy. And this energy (the ability to do work) was enormous, beyond that of any known fuel. Immediately there came into the minds of the scientists a possibility of a continuous process of breaking up atoms, called a *chain reaction*, to produce more energy.

If an atom in a sizable mass of uranium 235 were once split, atoms next to it could be split by the neutrons released from the first atom. The result might be a tremendous explosion in a millionth part of a second.

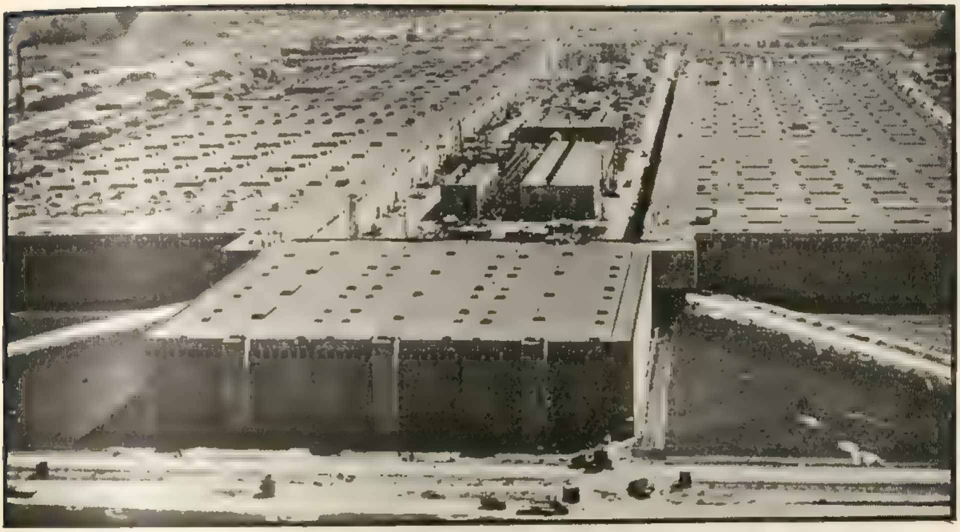
THE BIRTH OF THE MANHATTAN DISTRICT

In order to get speedy fission, it was necessary to secure a sizable mass of uranium 235 by separating it from ordinary uranium. This was particularly difficult because both kinds of uranium (uranium 238 and uranium 235) are chemically the same—the only difference is in weight. Could any means be found to separate uranium 235 from uranium 238 on a large scale? There was only one agency big enough to undertake the job—the United States government. The government was then interested in uranium 235 because of the possibility that such an explosive would hasten the end of World War II.

By the spring of 1943, the government had enlisted the best scientific brains of the nation to tackle atomic fission. Under the leadership of Dr. Vannevar Bush, the task of supervising the work of building an atom bomb was given to Major General Leslie Groves and Dr. Robert Oppenheimer. At Oak Ridge, Tennessee, were built the enormous plants for separating uranium 235 from ordinary uranium (Fig. 160). At



159
Enrico Fermi (left), with his collaborator, Walter H. Zinn. Fermi was in charge of the laboratory at Chicago, in December 1942, where crucial steps in the development of atomic energy were made. (U.S. Army Signal Corps)



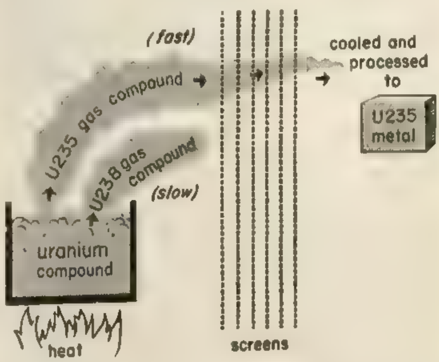
160 *The gaseous diffusion plant at the Oak Ridge National Laboratory, Oak Ridge, Tennessee. (U.S. Atomic Energy Commission)*

Hanford, Washington, other enormous plants were constructed. Over two billion dollars were invested in this project, even though no one was entirely certain it would succeed. The whole project was called the Manhattan District, and it was kept so secret that only a few of the top people working in it had a complete picture of what was going on.

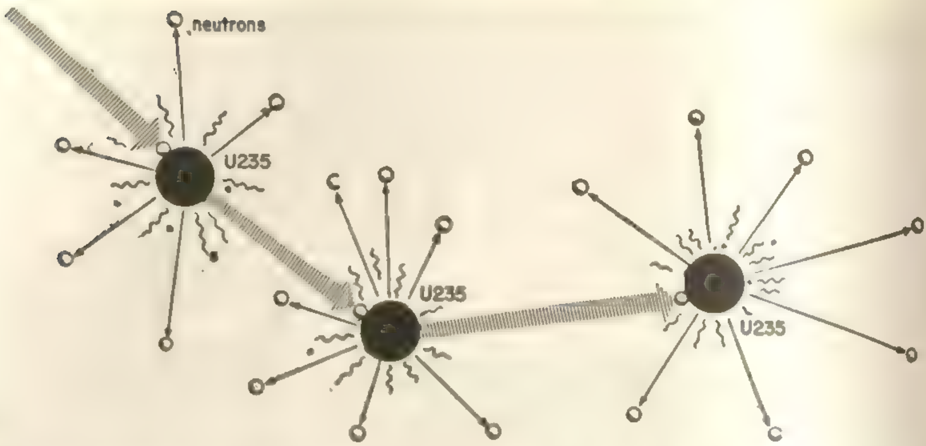
THE SEPARATION OF URANIUM 235

Because uranium 235 is a little lighter than uranium 238, one can be separated from the other by heating. A uranium compound is heated at very high temperature until it turns into a gas. This gas is passed through a fine screen. The molecules of uranium 235, being lighter than those of uranium 238, pass through the screen more rapidly (Fig. 161). They are immediately drawn away by pumps, but even so, many of the heavier molecules accompany them. To get the lighter uranium portion in a reasonably pure state, millions of square feet of floor space have to be used, and thousands upon thousands of these special screens are necessary, together with giant pumps for drawing the gas molecules through the screens. Finally, the lighter uranium comes out in pure vapor and is cooled and then processed to the solid metal, uranium 235. The difficulty of this process will be clear to you if you recall that in 140 parts of uranium 238 there is only one part of uranium 235.

Once pure uranium 235 could be



161 *Pumps draw the lighter uranium 235 (a gas) through porous screens faster than they do the heavier uranium 238.*



162 *Diagraming a chain reaction. Neutrons given off by an atom of uranium 235 strike other atoms. More neutrons are given off which strike more uranium 235 atoms, causing a chain reaction. At the same time, energy is given off.*

produced in quantity, the scientists at Oak Ridge had the kind of uranium that could start an immediate and terrific chain reaction. In other words, they now had the material to make an atomic bomb. Some of this uranium was sent to the University of Chicago where preparations had been made to set off the first chain reaction in history.

THE DISCOVERY OF PLUTONIUM

In December 1942, at the University of Chicago, Dr. Enrico Fermi had developed the atomic pile for producing atomic energy. Dr. Fermi tried another experiment. He placed slugs of both pure uranium 238 and pure 235 in pure carbon blocks and built them up into a circular construction of a certain size, called a *pile*. There a chain reaction took place, releasing tremendous energy in the form of heat. In such piles the fast-flowing neutrons of uranium 235, slowed down by passing through carbon, cause even atoms of the uranium 238 to split. The result is that the uranium 238 changes into an entirely new element which is highly radioactive. This new substance is given the name *neptunium*.

Neptunium itself changes rapidly into another element. Scientists found that this new element is highly fissionable. They called this second new element *plutonium*. So, on the trail of splitting the atom, scientists discovered the new elements neptunium and plutonium.

THE FIRST ATOMIC BOMB

The Manhattan District was not ended with the discovery of plutonium. In the experimental laboratories at Los Alamos in New Mexico, plans were laid for assembling the first atomic bomb. From the great plants at Oak Ridge and from Hanford came the vital materials—uranium 235 and plutonium.

Scientists know now that in the pure state uranium 235, as well as plutonium, must be kept in quantities below a certain size, called the *critical mass*. The reason for this is that even small amounts of these metals throw off quantities of neutrons. Some of these neu-

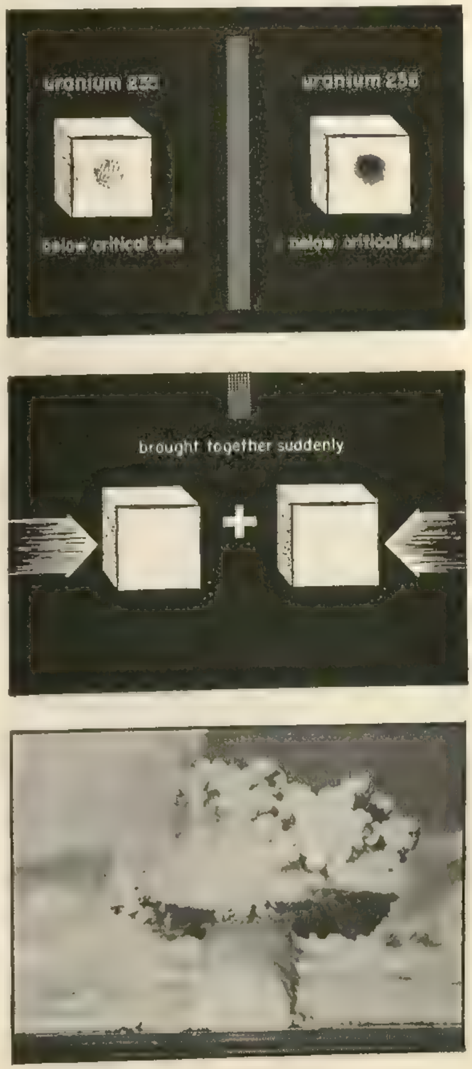
trons escape, but others may start a chain reaction as they hit other uranium 235 or plutonium atoms (Fig. 162). The possibility that this will happen increases when the amount of the material brought together is increased. Of course, the amount of material needed for an explosion as in the atomic bomb is a military secret. One guess is that a chain reaction occurs in a mass of uranium or plutonium weighing between 5 and 100 pounds. Chain reactions can be prevented by storing pure uranium 235 or plutonium in small amounts (below the critical mass) separate from each other. The first atomic bomb was designed to bring together two masses of uranium 235 at the proper second to make a mass beyond the critical size (Fig. 163). Since the explosion would occur immediately, the bomb had to be armed with a time mechanism set to force the separate quantities of uranium together as the bomb was about to explode.

IN THE HEART OF THE EXPLOSION

No previous accomplishment of man since the world began has matched the awful power released from within the atom. It was a great human triumph to turn a part of matter into energy by splitting the atom. Yet in turning matter into energy, man has only done what the sun and stars are doing day in and day out, year after year. The sun's heat and light are due to atomic explosions in which matter is transformed into energy. The sun loses 4,500,000 tons of its mass every second in giving off heat and light, but its bulk is so huge that it will still have 99.9 per cent of its mass left after another 15,000,000,000 years.

On this earth we get only a tiny fraction of the heat energy produced by the mass lost by the sun. The rest goes off into space. Probably all the heat that falls upon the earth in one second comes from a mass of the sun that you could carry in a paper bag—about five pounds. That will give you some idea of the unbelievable amount of energy that comes from the splitting of atoms.

163 *When two masses of uranium 235 or plutonium below critical size are suddenly brought together, the result is an atomic explosion. (Photo from U.S. Army Signal Corps)*



164 *These are corn plants grown from seed exposed to the radiation from the atomic bomb exploded at Bikini. Notice the three stunted plants.* (*California Institute of Technology*)

To produce the explosion of the first atomic bomb, there was a critical mass of uranium 235 that may have weighed between 5 and 100 pounds, and indeed may have weighed less. Yet it produced a temperature of 67,000,000 degrees Fahrenheit, a temperature so great that if a marble as hot as that should be placed on the desk in front of you, you and the entire contents of the room would immediately be burned to a crisp! Even a half-mile from the center of the explosion of an atomic bomb, the radiation of heat alone is sufficient to kill all life (Figs. 164 and 165).

Along with this terrific heat come showers of neutrons penetrating every object in their path over a large area, causing further atomic changes when any atomic nucleus is hit. The blast of air set in motion by the explosion is heavy enough to destroy buildings within a three-mile radius.

Yet only 0.1 per cent of the uranium 235 in the first bomb was consumed in the blast. That means that if the uranium 235 or plutonium in the bomb weighed 10 pounds, at the most, only about $\frac{1}{4}$ ounce caused the greatest explosion in the history of the world. Remember, however, that the amount of uranium 235 or plutonium used is a military secret.

165 *Corn grown from seed exposed to the atomic bomb at Bikini. Notice the damaged and undeveloped kernels.* (*California Institute of Technology*)

ATOMIC ENERGY

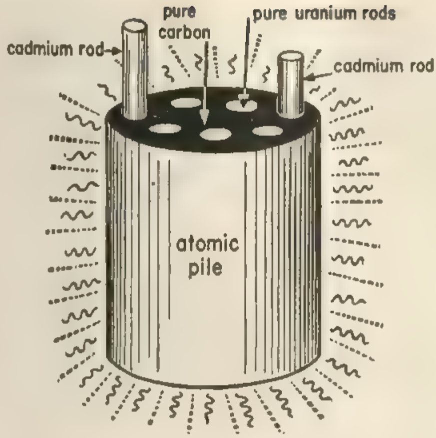
How can we use atomic energy? The end product of the Manhattan District was the atomic bomb. How about the peaceful uses of atomic fission? Can we use it for heating homes? running factories? speeding trains? Let us investigate.

Explosions such as are made by atomic bombs have no immediate peacetime use unless it is desired to blast away great chunks of the earth's surface. Atomic explosions on this scale cannot be controlled once they start. If atomic energy is to be used for peacetime purposes, it must be released without explosion. Can release of atomic energy be controlled?

Since it is the flow of neutrons that causes chain reactions in uranium, scientists figured that if they could find a substance that could stop or absorb the flow, they could control atomic energy. They found that substance in the element *cadmium,* a grayish metal. When cadmium rods are pushed into an operating pile, atomic fission slows down and finally stops. When these rods are pulled out, atomic fission begins again (Fig. 166).

Of course, this is all done by machines operated by remote control. A uranium pile in operation is enclosed in heavy walls because it throws off rays deadly to human life. Workers in both the Hanford and the Oak Ridge plants are carefully protected at work and they are examined daily. Even hair and clothing are inspected to see if they have been exposed to the harmful rays.

The piles in operation give off heat beyond human imagination. The plant at Hanford was built beside the Columbia River because it takes the entire water flow of that tremendous



166 *The flow of neutrons in an atomic pile is slowed up by the carbon. The number of neutrons which are free at any one time is controlled by inserting and withdrawing the cadmium rods. The cadmium rods absorb neutrons. Why are the cadmium rods movable?*

river, cold as it is, to carry away the heat generated by the operating piles. Twenty miles below Hanford, the water is still five degrees higher in temperature than the water above. The water is not contaminated because it does not touch any radioactive substance. It is this heat energy from an operating pile that appears to be the most usable form of atomic energy at present for replacement of various fuels and for heating purposes.

WILL ATOMIC ENERGY REPLACE COAL AND OIL?

About 500,000,000 tons of coal are mined in the United States every year. Two hundred tons of uranium 235 would produce the same amount of heat that this quantity of coal produces. About 40,000,000,000 gallons of oil are produced annually in the United States. Thirty tons of uranium 235 contain the energy that can be pro-

duced from this amount of oil. Then why would it not be better to produce 230 tons of uranium 235 than 500,000,000 tons of coal and 40,000,000,000 gallons of oil every year? The answer is that at present neither the United States nor any other country is ready to replace coal or even partly replace oil with atomic energy.

Given the most favorable conditions at the present time, power derived from atomic energy would be more expensive than power from coal or hydroelectric plants in this country. In addition there is the problem of getting enough uranium ore. Great quantities of ore are needed to produce even a pound of uranium 235. There is a limited supply of ore in this country.

Many problems have to be solved and much work still has to be done to make atomic energy cheaper than other fuels. One major problem, for instance, is the deadly rays that come from an operating pile or from uranium 235. Researchers must learn how to shield people from these rays cheaply and effectively. No doubt within the next few years we shall see a beginning toward the use of atomic energy as fuel, but substitution of atomic energy for fuels now in use will not come overnight.

However, research now going on suggests that radioactive materials produced by the heavy operating piles instead of the piles themselves may be used as the source of atomic fuel. With these materials, less shielding is necessary and less room is needed since the heavy piles themselves are not essential.

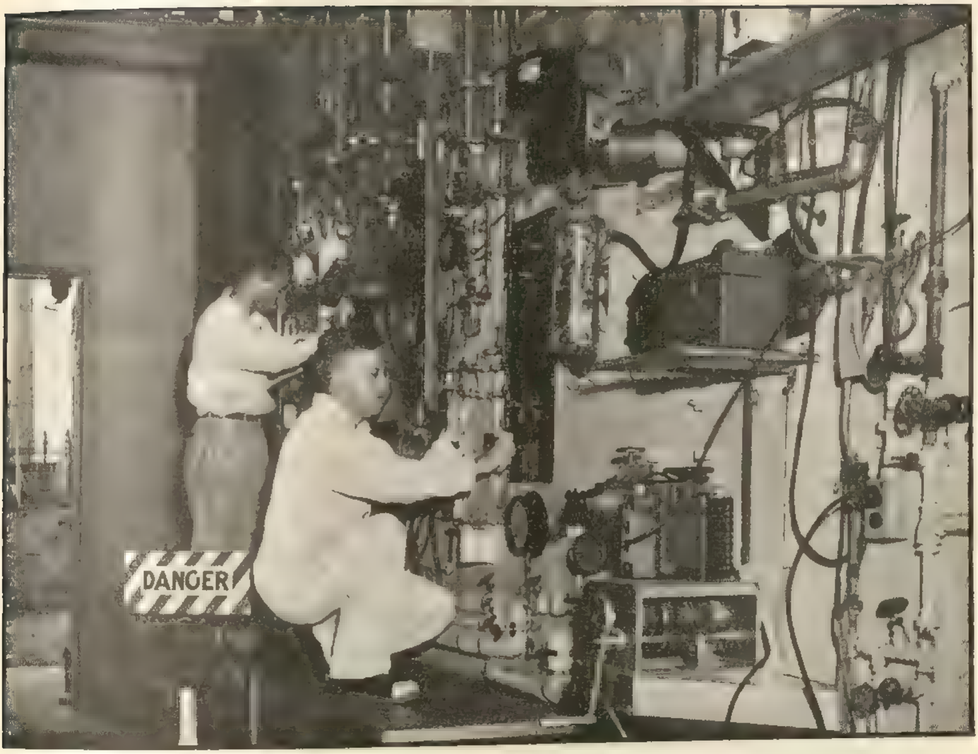
ATOMIC ENERGY FOR THE LOCOMOTIVE, STEAMSHIP, AND AUTOMOBILE

Not long after the news of the atomic bomb was given to the world, the wildest ideas began to spread. Said one newspaper article: "We will be able to drive the largest steamship afloat to Europe and back on the energy contained in a glass of water." Said another: "We can build automobiles with a pellet of uranium 235 installed as fuel to last the life of the car." Still another announced: "It won't be long before jet-powered airplanes can fly to the moon and back."

Let's look at the facts. The necessity for shielding people from the heat and radioactivity of even a small operating pile would take a considerable weight of heavy material. There is at present no engine invented that can use the energy of a pile directly, although several industrial companies are working on the problem of using the energy from products of the pile. Furthermore, at today's price of fissionable materials, locomotives, automobiles, and steamships can use their present fuels more cheaply. There is, of course, a great need for a lighter fuel than gasoline for airplanes. With atomic energy, pilots could use the space and weight now taken by gasoline for the transporting of greatly increased cargoes over longer distances. Yet, there again is the problem of shielding the pilot and designing a suitable engine. And there is no way we know to release enough energy from a glass of water to drive a steamship to Europe and back.

However, it seems probable that the first use of atomic energy, when it is made, will be in ships of the United States Navy. This will eliminate the large weight of oil now carried and the necessity for refueling at sea.

Man produced the atomic bomb. In so doing, he hurdled almost impossible obstacles. It seems reasonable to believe that he will solve the problems of shielding and engine design, and others that stand in the way.



167 *Producing radioactive materials in an operating atomic pile. The scientists are working by remote control. Why is this necessary?* (*U.S. Army Signal Corps*)

USING RADIOACTIVE MATERIALS IN RESEARCH

Today the most valuable contribution of the Manhattan District to peacetime living is the making of radioactive materials for medical, agricultural, and industrial use. This is done primarily in the atomic piles at Oak Ridge (Fig. 167). When bombarded by neutrons from the operating piles, atoms of most elements become radioactive. The neutrons cause a change in the atomic structure of the elements. For example, stable atoms of nitrogen with atomic weight of 14 are changed by this neutron bombardment into unstable, radioactive carbon atoms with atomic weight of 14. The unstable carbon 14 changes back into nitrogen and in so doing gives off strong radiation. This radiation is picked up and measured by sensitive instruments called Geiger counters.

Thus it is possible to make almost any element radioactive; that is, to give it the property of emitting rays. The Atomic Energy Commission is now producing over 100 different radioactive substances in the laboratories at Oak Ridge. Some of these substances were made in small quantities and at a high cost in cyclotrons before World War II. Now they are available in great quantity and at a low cost for all kinds of research. For example, in just a few weeks an Oak Ridge pile produced at a cost of $10,000 an amount of carbon 14 that would equal the product of 1,000 cyclotrons at a cost of $100,000,000. There

were in 1949 almost 2,000 research projects in this country using radioactive materials supplied by the Atomic Energy Commission.

USING RADIOACTIVE MATERIALS

Carbon 14 is only one of many varieties of radioactive materials distributed at the present time from Oak Ridge, but it constitutes about one shipment out of every ten. Examples of other important shipments are radioactive phosphorus, iodine, calcium, sulfur, iron, zinc, and cobalt. These radioactive materials are used as tracers, that is, as tagged atoms, as they take part in reactions in the bodies of plants and animals and in chemical processes. When we say "tagged," we mean that the radiation given off by these substances is traced by the Geiger counter as the substances take part in chemical actions and as they move through the bodies of plants and animals.

This tracing of tagged atoms has given scientists an opportunity for the first time to study in detail the fundamental processes of nature taking place in the manufacture of food by green plants; in the tearing down and building up of living cells; in the chemistry of fuels and other energy-producing substances. Already, by the use of tagged atoms, medical knowledge of the working of the human body has been advanced many years. The battle against disease, including cancer, has been speeded up. No less important, these tracer processes will enable man to provide for better uses of nature's resources.

PROJECTS WITH TAGGED ATOMS

Here are just a few of the projects of radioactive research:

1. How fast do certain food substances, like iron, get into the blood? Harmless radioactive iron is fed to people. Then a Geiger counter is placed near the wrist pulse. It has been found that in about 24 hours the iron has traveled from the mouth, passed through the intestines and into the blood. Since iron is used in treating some forms of the disease anemia, experiments like this may lead to improved methods of treating the disease.

2. How fast are life processes? Experiments with table salt containing radioactive sodium have measured the speed of life processes. When taken into the human body the salt is "diffused through the walls of the veins, transported to the sweat glands, converted into sweat, and carried to the surface of the body, all in less than one minute's time. It has been discovered that the transfer of fluid in and out of the human veins is so rapid and continuous that it carries back and forth with it 50 pounds of salt, on the average, each day."[1]

3. How can we measure the activity of the thyroid gland? Thyroid gland diseases have always been difficult to diagnose, but it is known that they are directly associated with the degree of the gland's activity. Since the thyroid picks up almost all the iodine in the body, by feeding a person a small and harmless dose of radioactive iodine the degree of activity of the thyroid gland is determined. This is done by holding a Geiger counter near the gland and noting the rate at which the gland absorbs the radioactive iodine (Fig. 168).

4. How do radioactive materials help agriculture? By using radioactive materials as tracers, scientists have been able to get a much clearer picture of how green plants manufacture food. By feeding plants carbon 14 and radioactive minerals that plants procure from the soil, scientists gained impor-

[1] Fourth Semiannual Report, United States Atomic Energy Commission.

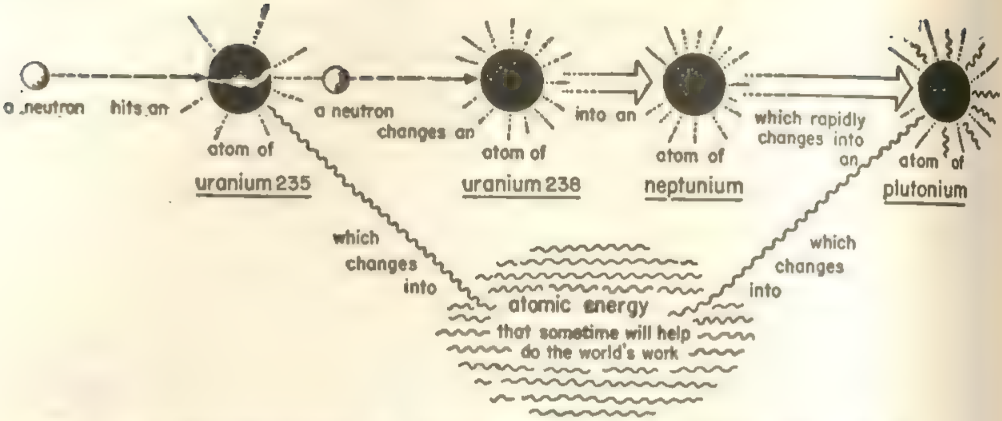
tant knowledge about how green leaves manufacture starch out of sunlight, water, and carbon dioxide, how the roots of plants pick up the minerals and organic matter from the soil, and how these in turn are disposed of in the bodies of the plants.

The results of these studies have given new knowledge concerning what type and kinds of substances plants need in certain stages of their growth. This will eventually result in the development of varieties of plants that will produce more heavily. This will in turn assist the faster growth of cattle and other animals that feed upon plants. At the same time the results of the studies have determined what kinds of fertilizers are suited to the best growth of specific crops. This is indeed of great importance when farmers in the United States spend half a billion dollars each year for fertilizers.

5. How do radioactive substances help industry? There are many applications of radioactive materials to industry. By using carbon 14 in the petroleum industry, scientists have been able to follow the changes as gasoline is made from crude oil. They can also better study processes for making gasoline from coal and natural gas. And by injecting other radioactive substances into oil pools at the bottom of oil wells, scientists can even trace the underground course of the pools.

"In the steel industry, radioactive carbon, phosphorus, sulfur, and other elements help determine the source and quantity of these impurities in molten batches of steel. . . . In the rayon industry radioactive sodium measures

168 *Using a Geiger counter to trace radioactive iodine used in treating thyroid cancer. (Paul Parker)*



169 *A diagram summarizing the changes in atoms which produce atomic energy.*

accurately the coating on a tiny fraction of an inch of thread so fine that it weighs less than one millionth of an ounce to the inch."[1]

These are but samples of the uses to which radioactive substances are put. There are many others, such as the battle against cancer with radioactive cobalt; tracing the function of the respiratory system with radioactive argon; the study of the functioning of nerves with radioactive potassium. More and more projects and uses for radioactive substances are being found each day.

LOOKING BACKWARD AND FORWARD

Now that you have become acquainted with the history of atomic energy and some of its uses, it is much easier for you to understand a diagram such as Fig. 169.

Yes, it looks quite simple on paper. But how much time, effort, and money have gone into it. We are only at the beginning of our knowledge of atoms and atomic energy. But scientists are optimistic. Many of them believe that your generation will see atomic energy used on a large scale as a common source of energy.

[1] Fourth Semiannual Report, United States Atomic Energy Commission.

GOING FURTHER

1 *Words are ideas.* Can you use these words in a sentence which will give their meaning? Use the glossary.

uranium	remote control
atomic fission	atomic energy
cyclotron	plutonium
pitchblende	neptunium
atomic pile	carbon 14
cadmium	

2 *Put on your thinking cap.*

In September 1949 President Truman announced that there recently had been an atomic explosion in the U.S.S.R. In his statement he said, "Nearly four years ago I pointed out that 'scientific opinion appears to be practically unanimous that the essential theoretical knowledge upon which the discovery is based is already widely known. There is also substantial agreement that foreign research can come abreast of our present theoretical knowledge in time.' " President Truman's announcement emphasized the necessity for a "truly effective and enforceable international control of atomic energy."

1. Why had it been expected that other nations would soon have an atomic pile and atomic bombs?

2. What instruments may have been used to detect the atomic explosion in the U.S.S.R.?

3. Why is there a need for international control of atomic energy?

4. What does President Truman's phrase, "essential theoretical knowledge," mean?

3 *Test yourself.* In your notebook, complete the following sentences with a correct word or phrase. Do not mark this book.

1. Uranium is found in an ore called ....
2. The ...... is an instrument that shoots atomic particles at a target with unbelievable speed.
3. Two new elements made by scientists are ...... and ....
4. Rods of cadmium govern chain reaction in the ....
5. An atomic explosion occurs as a result of a ...... reaction of atoms.
6. Amounts of uranium 235 or plutonium must be kept below a certain size, called ....
7. The splitting of an atom is called atomic ....
8. Atomic piles produce energy in the form of ...... that may some day operate factories.
9. To guard against deadly rays coming from atomic piles, the piles must be ....
10. ...... materials produced from atomic piles are used to help study certain life processes.

4 *Adding to your library.*

1. *Secret* by Wesley Stout, Chrysler Corp., 1947. The story and pictures of the making and explosion of the atomic bomb.
2. *Mr. Tompkins Explores the Atoms* by G. Gamow, Macmillan, 1944. Lively story of what the atom contains.
3. *Almighty Atom* by John J. O'Neil, Ives, Washburn, Inc., 1945. History and description of atomic energy.
4. *Dawn over Zero* by William L. Laurence, Knopf, 1946. A firsthand story of the explosion of the first and third atomic bombs.
5. *The World Within the Atom* by L. W. Chubb, Westinghouse Electric Corp., 1946. A clean-cut story of the development of our knowledge of the atom.
6. *Why Smash Atoms?* by Arthur K. Solomon, Harvard University Press, 1946. An interesting book explaining the cyclotron, with a good number of pictures of the development of the atomic bomb.

CHAPTER 14

THE CHEMICALS AROUND YOU

On the slope of a mountainside, a man is busily working. Pushing an empty wheelbarrow, he enters a hole in the slope. In about half an hour he reappears, his wheelbarrow full of reddish-colored earth. He shovels the earth into small sacks.

A thousand miles away a pipe line runs out into the ocean. Every day millions of gallons of sea water rush through the pipe into a large, brick building. There the sea water is treated with chemicals. After a while the sea water is pumped out of the building, back into the ocean. But it has left in the building some of the valuable material it contained.

On the outskirts of a busy city in another part of the country, a sign above a factory reads: "Air Reduction Products Corporation." Inside can be heard the movement of machinery. Pumps move back and forth. Air—the air you breathe—is made so cold by this machinery that it turns into a liquid. Then this liquid air is separated into pure gases.

What connection have these activities with each other? In the first, a miner is digging a red ore of mercury from the earth. In the second, magnesium (măg nē′shĭ ŭm) is being extracted from sea water. In the third, oxygen is being separated from liquid air. These three widely different activities are alike in one respect. In each case a useful substance is being removed from the crust of the earth, the waters of the earth, or the earth's great envelope of air.

Of course, not all the materials making up the world are as valuable as mercury, magnesium, or oxygen. But no matter how many our wants or how rich we are, the substances that satisfy our wants and make us richer come eventually from the earth, its water, and its air. In this chapter, you will learn what some of these things are, how chemists name them, and how much of them the world contains. You will explore the earth, the waters of the earth, and the air surrounding the earth. You will find that no matter where you go, or what you do, you are dealing with the chemicals of Nature's great storehouse. You will also see why many people are greatly concerned over the wasteful use of these resources. Even a storehouse may be emptied.

BENEATH YOUR FEET

Scientists have discovered that there are 92 elements in the world. (Four more, as you know, were produced by atomic scientists.) Some of these elements are very scarce, while others may be found almost anywhere in mixtures or in compounds. Careful analysis of the solid earth, the ocean, and the air shows that the most abundant elements are oxygen, silicon, aluminum, iron, calcium, magnesium, sodium, and potassium.

You can see by Table III, page 98, that 8 of the 92 elements make up about $98\frac{1}{2}$ per cent of the entire earth; the other 84 make up only $1\frac{1}{2}$ per cent. Of these 84 elements, 77, including gold, silver, and uranium, make up less than 0.1 per cent of the whole earth! These figures show why some elements are rare and difficult to find.

THE CHEMIST'S SHORTHAND

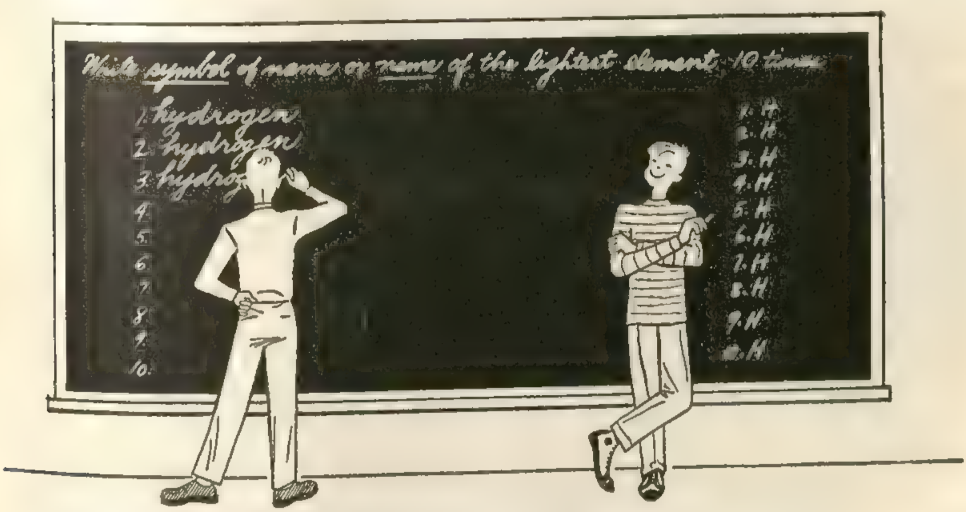
If you had to write the words oxygen and hydrogen fifty times, wouldn't you be interested in saving time and energy by shortening the words (Fig. 170)? Chemists find it easier to write formulas for molecules of compounds, if they can use symbols like H for hydrogen and O for oxygen, instead of writing the names of these elements. H_2O is the chemist's formula for water because:

1. H_2O is the simplest way to write the word water.

2. H_2O represents a molecule of water in which H_2 represents two atoms of hydrogen and O one atom of oxygen (see p. 219).

Chemists have devised a shorthand for all known elements. Examine Table VI on page 246. Note that most symbols are very simple. They consist of the first or two of the first few letters of the name of the element: S for sulfur; N for nitrogen; Al for aluminum; Ca for calcium. Other symbols are somewhat different, such as Na for sodium, Fe for iron, Au for gold, and Ag for silver. In any case, it is much easier to write a symbol than to write the name of the element.

You, too, will find it easier to use symbols for elements as you continue the study of science. When you want to write the formula for a molecule of



170 *Isn't it quicker to write symbols for elements instead of their names?*

Table VI. SOME COMMON ELEMENTS

Name	Appearance	Common way or ways element occurs	Symbol	Atomic weight
aluminum	light, shining, grayish-white metal	combined with oxygen in clay	Al	27.
bromine	reddish-brown liquid	combined with magnesium in salt water	Br	80.
calcium	grayish-white metal	combined with carbon and oxygen in marble	Ca	40.
carbon	sparkling (diamond) black (coal, graphite)	by itself as coal, diamond, graphite	C	12.
chlorine	greenish-yellow gas	combined with sodium in table salt	Cl	35.5
copper	shining reddish-brown metal	by itself and in ores of copper	Cu	63.6
gold	yellow metal	by itself	Au	197.
helium	colorless gas	by itself in natural gas	He	2.
hydrogen	colorless gas, lightest known	combined with oxygen in water	H	1.
iodine	salty gray solid	combined with sodium in seaweeds	I	127.
iron	grayish-white metal	combined with oxygen	Fe	36.
lead	bluish-white metal	combined with sulfur	Pb	207.
magnesium	light silvery-white metal	combined with sulfur	Mg	24.
mercury	heavy silvery-white liquid	combined with sulfur	Hg	200.
nitrogen	colorless gas	by itself in air	N	14.
oxygen	colorless gas	by itself in air and combined with hydrogen	O	16.
platinum	heavy white metal	by itself	Pt	195.
potassium	soft silvery-white metal	combined with oxygen in wood ashes	K	39.
radium	grayish-white metal	in ore called pitchblende	Ra	226.
silver	white shining metal	by itself and also combined with sulfur	Ag	108.
sodium	soft silvery-white metal	combined with chlorine in table salt	Na	23.
sulfur	yellow solid	by itself and combined with metals	S	32.
tin	soft white metal	combined with oxygen	Sn	119.
uranium	heavy white metal	by itself and combined with other elements like oxygen	U	238.

copper oxide, it is very convenient to jot down CuO, which means that one atom of copper has combined with one atom of oxygen to form one molecule of copper oxide. You will also recognize the meaning of formulas such as these:

$NaCl$ One atom of sodium has combined with one atom of chlorine to form one molecule of table salt.

$NaHCO_3$ One atom of sodium has combined with one atom of hydrogen, one atom of carbon, and three atoms of oxygen to form one molecule of baking soda.

$C_{12}H_{22}O_{11}$ Twelve atoms of carbon have combined with 22 atoms of hydrogen and 11 atoms of oxygen to form one molecule of cane sugar.

And now you are ready to study the formation of minerals and ores.

FROM ELEMENTS TO MINERALS AND ORES

Do you know how most gold rushes start? Someone finds particles of gold

in a stream bed or in a rock. From that time on, it is everyone for himself. But one good thing about searching for gold is that prospectors know what to look for. Gold is found free in nature; it is not combined with other elements. All but a few elements in the earth are found combined with other elements. That may be explained in this way. When the earth was very young, it was also very hot. Atoms of most elements combined with atoms of other elements as the earth cooled. The compounds they formed make up most of the minerals that exist today. A *mineral* is any substance occurring naturally in the earth's crust.

Now look again at Table III. Would you expect the most abundant elements to be part of the most common minerals? That's just what happens. Silicon and oxygen are found combined everywhere as sand or quartz (SiO_2) or as parts of clay and mica. Mica is a compound of magnesium, hydrogen, silicon, and oxygen.

Granite, one of our common rocks, is made up in part of a mixture of quartz and mica. And clay and sand and rock particles make up most of the earth's soil that you walk on every day of your life.

Hundreds of other minerals exist. Those minerals from which we get useful metal elements are called ores. The miner in the introduction to this chapter was digging cinnabar, a red ore of mercury, from the mountainside. Certainly this red ore of mercury looks nothing like the silvery white liquid in the bulb of your thermometer. That is the case with most metals: you won't find them in the pure state, nor will their ores look as if they contained the metal element. For example, you won't find pure lead if you go looking for that metal. It will probably be part of heavy shiny crystals known as galena (gȧ lē′nȧ). Pure iron is never found by itself in nature. It is usually part of the reddish or purple ore called hematite (hĕm′ȧ tīt). The shiny white metal aluminum comes from a grayish-white clay known as bauxite (bôks′īt, Fig. 171).

So it goes. Unless the element occurs free, like gold or platinum, it is part of a mineral that is entirely different in appearance. And these minerals are everywhere in the earth's crust—even in ocean water and in the water you drink.

WATER—THE UNIVERSAL SOLVENT

Water dissolves more things than does any other liquid. The chemist relies upon the dissolving power of water to make chemicals react with each other. Your body relies upon water to dissolve the digested portions of the food you eat so that they can be easily taken up by the cells.

WHY IS THE OCEAN SALTY?

Whenever water comes in contact with soil, it dissolves some minerals. Even your pure drinking water contains some minerals. You can prove this by taking an absolutely clean saucer and filling it with tap water. Let the saucer stand in a warm place a few days until all the water has evaporated. The film you see on the bottom of the saucer is made by the small amount of mineral matter that is ordinarily dissolved in tap water.

In the same way, the scale which forms on the inside of the bottom of your tea kettle comes from minerals that have settled out of the boiling, over a long period of time. Water pipes of cities may become clogged by the min-

eral deposits from millions of gallons of water flowing through them.

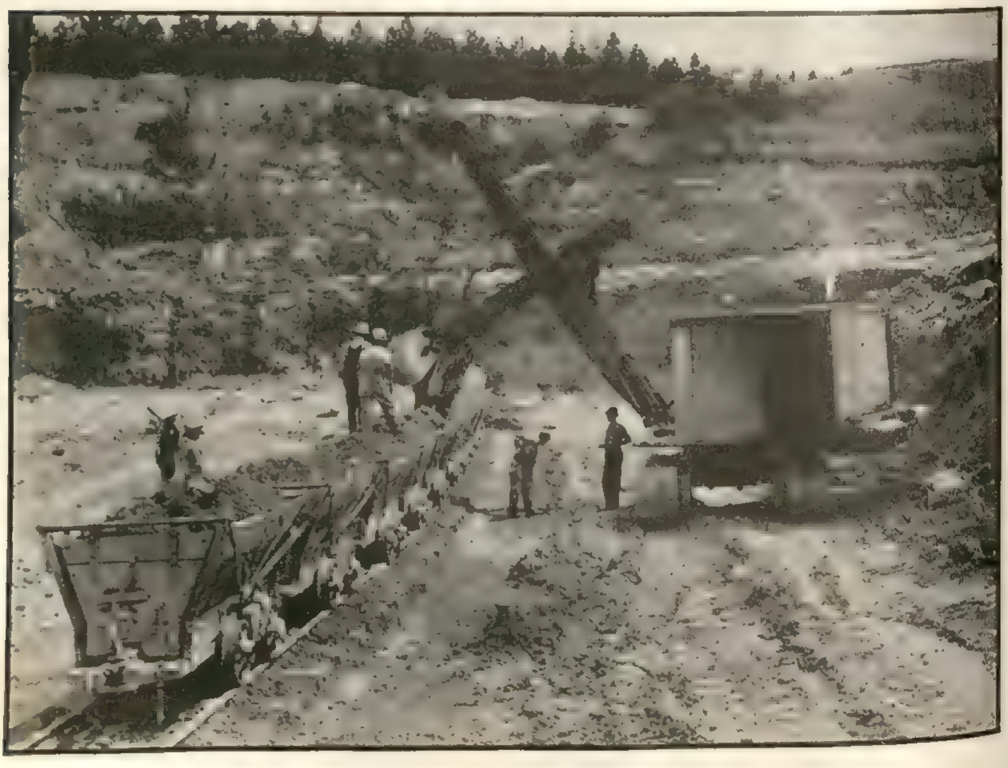
From the time of the first rainfall, river water and surface drainage have poured minerals into the oceans. When we say that the ocean is salty we mean that its content of dissolved minerals is high. Whenever there is no natural outlet in a body of water, that body of water holds the minerals. When water evaporates from the surface the minerals are left behind. This is the reason for the great amount of salt in the Great Salt Lake in Utah and in the Dead Sea in Palestine.

DISSOLVED MINERALS ARE VALUABLE

Three-quarters of the earth's surface is covered by oceans. Every glass of this sea water contains about a teaspoonful of crude salt. This is mainly table salt ($NaCl$). But there are also small amounts of other salts such as magnesium chloride ($MgCl_2$) and magnesium bromide ($MgBr_2$). It is said that if all the minerals could be extracted from the oceans, they would cover North and South America with a blanket 400 feet deep.

A cubic mile of ocean water contains about nine million pounds of magnesium (Mg) and a large amount of bromine (brō′mēn, Br). A way to extract these two elements from sea water was found about 25 years ago. Every day millions of gallons of sea water are pumped through extracting plants like the one mentioned at the beginning of this chapter. About 200,000 tons of magnesium and 35,000 tons of bromine

171 *Loading mine cars with bauxite ore from an open-pit digging. America has enormous resources in bauxite. (Aluminum Company of America)*



are used in the United States each year. Nearly all this bromine and much of the magnesium come from minerals of the sea.

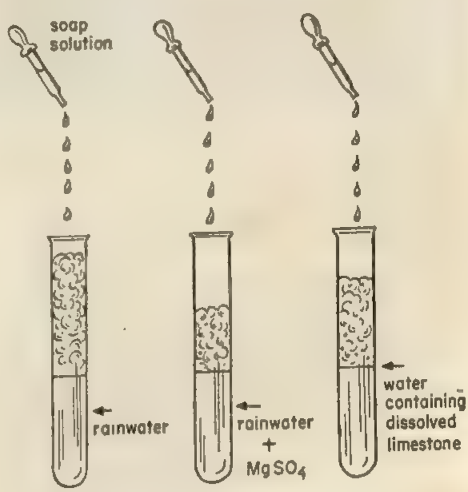
But dissolved minerals have other values. They help to give drinking water its flavor. In regions where some minerals are more soluble than others, this flavor is very noticeable. Yet most mineral matter in drinking water is perfectly harmless—in fact, some is beneficial. The small quantities of a mineral containing iodine found in natural water prevent one kind of simple goiter, a growth of the thyroid gland, which is located in the throat. When water is lacking in this iodine-containing mineral, as in some parts of Switzerland, Turkestan, and even in some districts around our own Great Lakes, many cases of simple goiter occur. However, iodized salt has rid the Great Lakes region of most cases of simple goiter. In some sections of the country, water contains fluorine (flōō′ô rēn), believed to help prevent tooth decay.

HARD WATER

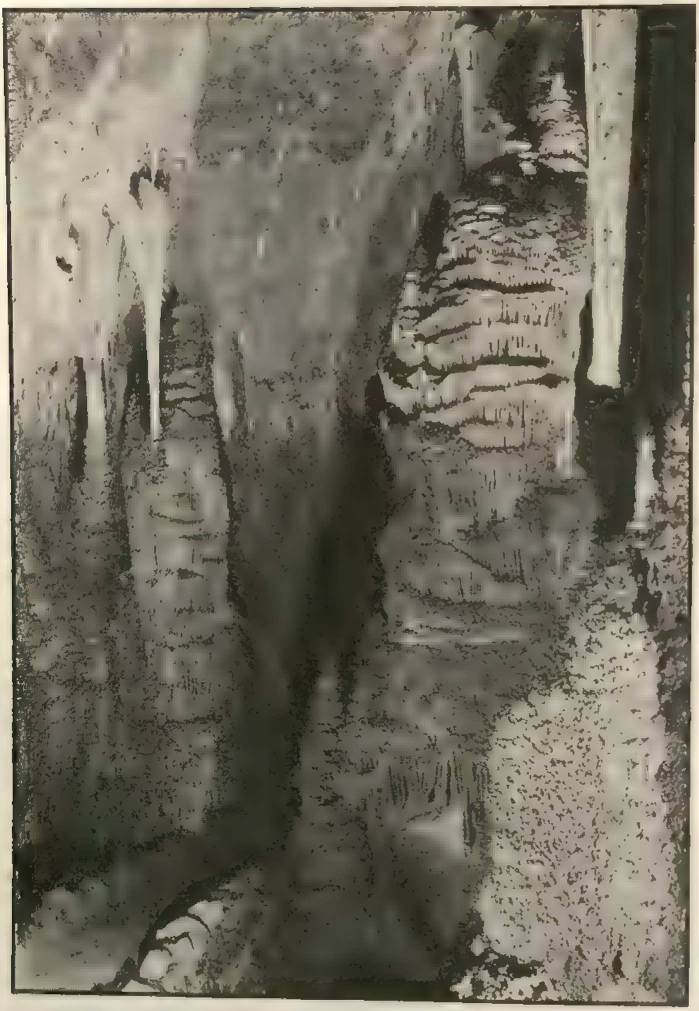
Water in which soap does not lather easily is called hard water. Hard water contains dissolved salts of magnesium and calcium. In the presence of these salts, soap does not dissolve in the water, with the result that much of its cleansing action is lost. Would you call sea water hard water? It certainly is. Ordinary soap feels like grease when it is used with sea water. Try it sometime when you are swimming in the ocean.

To show how the cleansing action of soap is affected by dissolved minerals, fill two test tubes one-third full of rain water or distilled water. These are soft waters containing no minerals (Fig. 172). Fill a third test tube one-third full of limewater. Using a medicine dropper, allow five drops of a liquid soap to fall into one of the test tubes of rain water. Shake it to form suds. Now add a pinch of magnesium sulfate (Epsom salts, $MgSO_4$) to the second test tube of rain water. Add five drops of soap solution and shake it. Do you get as many suds as in the first tube? Would your expenses for soap be larger when using hard water or when using soft (rain) water?

Now blow your breath carefully through a straw into the test tube of limewater. The carbon dioxide (CO_2) of your breath reacts with the limewater to form particles of calcium carbonate ($CaCO_3$), really a form of limestone. If you keep on blowing, the milky color will disappear. The calcium carbonate dissolves when an excess of carbon dioxide is blown into the liquid. A soluble compound, calcium bicarbonate, is formed; this makes the water hard. How many drops of soap must you add to this test tube to get suds equal to that in the first test tube



172 *Does it take more soap to make suds when using rain water or when using water containing dissolved minerals?*



173
Stalactites and stalagmites often join to make beautiful cave formations. Which hang from the roof? (National Park Service)

containing rain water? You will find that you may have to add three or four times as much soap. What do you conclude about the increased expense of using soap in regions where water has dissolved limestone from the earth?

How would you solve the problem of washing clothes in hard water? Wouldn't you try to soften the water, that is, add something to it that would counteract the action of the magnesium or calcium salts? That is just what many housewives do. Washing soda or borax or a little ammonia added to hard water will help. Commercial water softeners, which extract the magnesium and calcium salts, are also used in many regions where the water is extremely hard.

LIMESTONE CAVES

You may have heard of or visited the Mammoth Cave of Kentucky, the Luray Caverns of Virginia, or the Carlsbad Caverns of New Mexico. If you have, no doubt you have wondered how such immense caverns were formed.

The earth contains a great deal of water beneath its surface. Much of it

contains carbon dioxide. During countless ages, this underground water bearing carbon dioxide has dissolved the limestone far below the earth's surface, leaving great holes where the limestone once was. These open spaces form the caves we know today.

When underground water evaporates from the roofs or floors of these caverns, the dissolved limestone is left behind and it often builds up into beautiful formations. The formations hanging from the roofs are called stalactites (stȧ lăk′-tīts). The formations which are built up from the floor are called stalagmites (stȧ lăg′mīts). Stalactites and stalagmites attract the attention and admiration of thousands of visitors to the famous caves (Fig. 173).

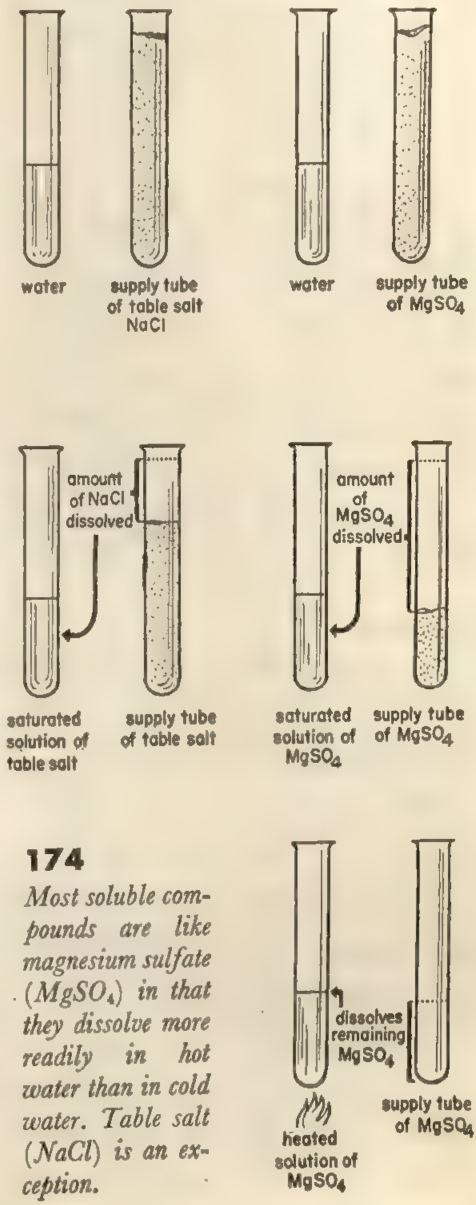
HANDMADE SOLUTIONS

Of course water dissolves many things besides limestone. It also dissolves some substances better than it does others. To demonstrate this, fill two test tubes one-third full of water (Fig. 174). Now fill a third tube with table salt and a fourth test tube with magnesium sulfate (Epsom salts). From these supply tubes add a portion of table salt to one of the tubes containing water, and magnesium sulfate to the other.

Add the salts and shake until no more salt or magnesium sulfate can be dissolved. You have reached a point where the solution in one test tube is saturated (săt′ū rāt′ ĕd) with the table salt. In the other tube the solution is saturated with magnesium sulfate. A saturated solution is one that will hold no more of the dissolved substances at that temperature. Now examine the levels of the table salt and the magnesium sulfate in the supply test tubes. Which one is the lower (Fig. 174)? Which of the two substances dissolves more readily?

Next, take the test tube containing the saturated solution of magnesium sulfate and heat it. Now try to dissolve more magnesium sulfate in the solution. Are you successful?

You have seen by this experiment that some substances, like table salt, do not dissolve in water as readily as other substances, like magnesium sulfate. You



174
Most soluble compounds are like magnesium sulfate ($MgSO_4$) in that they dissolve more readily in hot water than in cold water. Table salt (NaCl) is an exception.

have shown that there is a point—the saturation point—beyond which no more of a substance can be dissolved at a certain temperature. And you have proved that if you increase the temperature, a larger amount of the solid can be dissolved.

Gases can also be dissolved in water; CO_2, for example, is dissolved in ginger ale. Increasing the temperature of the solution, however, decreases the amount of a gas you can dissolve. With most solids, increasing the temperature increases the amount of material dissolved.

How does all this apply to your daily life? A scientist, a doctor, or a druggist must know what substances will not dissolve at all, what substances dissolve moderately, and what substances dissolve readily. In making solutions or in compounding medicines, they must know or be able to find the saturation point of a solution. And, like your mother when she cooks, they must know that by heating water, they can dissolve more of a solid substance in a shorter space of time.

SUSPENSIONS

Many solids are insoluble yet are still carried by water. These substances are plainly seen, as in a glass of muddy water. When water contains very small particles of a substance like soil, it is called a *suspension*. Familiar suspensions in your home are fresh milk, gravy, starch in water, and mayonnaise. Many suspensions, such as muddy water, settle if they are left standing.

Suspensions play a great part in changing the earth's surface. The tremendous amount of soil carried in suspension by the Mississippi River builds the river delta 250 feet farther each year into the Gulf of Mexico. In a similar way, the Nile and the Danube rivers increase the size of their deltas 13 feet each year. Whenever soil is carried away from one spot on the earth's surface and deposited in another, suspensions are mainly responsible.

ABSOLUTELY PURE WATER

How can we obtain water without anything dissolved or suspended in it?

It is often necessary to remove all impurities from water. Chemists, doctors, druggists, and manufacturers need water free from all dissolved material. Pure water is obtained by *distillation*. In this process impure water is boiled to form steam. Boiling kills any harmful organisms that may be present, and no dissolved solids pass off with the steam. When this steam cools in the condenser of the distilling apparatus, water forms again, free of impurities.

No doubt your school has a distillation apparatus something like the one in Fig. 175. You may see how it works by filling a large flask one-half full of copper sulfate solution. Attach it to a condenser as is shown in Fig. 184. Boil the copper sulfate until a colorless liquid drips from the condenser tip into the beaker. This process is called distillation. The water, free from impurities such as the copper sulfate, is called distilled water.

AIR—AN INVISIBLE OCEAN

On a clear evening, as you look up into the sky you cannot see anything between you and the moon or the stars. Yet you know that a great quantity of air stretches out above you.

How high does the air extend above the earth? No one knows, but it is safe to say that there is at least a little air

at a height of 500 miles. Next to the earth the air is densest, heaviest; at sea level it presses upon everything with a weight of 14.7 pounds per square inch in all directions—upward, downward, and sideways.

WHAT IS AIR MADE OF?

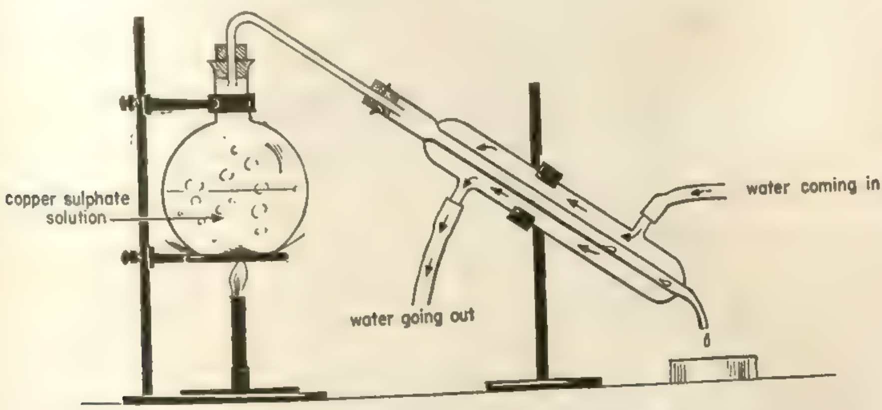
Of course you know there is oxygen in air. But did you know that neon, the gas that causes the red glow in advertising signs, is a part of air? Or that the argon or nitrogen gases that fill electric light bulbs are also a part of air? About 1 per cent of air is composed of argon, neon, and a few other rare gases. Most of the rest of air—about 79 per cent—is nitrogen, and about 20 per cent is oxygen. Water vapor and a small amount of carbon dioxide, as well as dust particles, are always found in the air.

OXYGEN—SUPPORTER OF LIFE

What would happen if the air were pure oxygen? With every breath, you would draw in five times as much oxygen as you breathe now. Immediately, you would feel tremendously excited and active. You would probably run faster than you had ever run before. You would overtax your strength and your heart. Shortly, you would die. However, before that time someone might have struck a match, or a glowing ember might have blazed up somewhere. If that happened, whole cities and towns would burn up in a twinkling. Even iron would burn. Probably the whole world would soon be lifeless and barren.

Nitrogen in the air dilutes the oxygen and we can breathe and live naturally. Nitrogen is called an inactive gas; oxygen, an active gas. At ordinary temperatures, nitrogen does not react (combine chemically) with anything; oxygen reacts with many things, even with the substances in the tissues of our bodies.

When we take air into our lungs, the oxygen in air is carried to every portion of the body by the blood. It unites with the food in the cells. The combining of oxygen with another substance is called *oxidation*. The process of oxidation is described fully in Chapter 16. Right here it is enough for you to know that, as a result of oxidation of food in the cells, carbon dioxide and water are produced. They are carried back to the lungs by the blood. There they are exhaled.



175 *Boiling a solution of blue copper sulfate in the flask produces colorless, pure water which comes from the condenser. Does distillation of water remove impurities?*

The oxygen in the air has been used by plants and animals since life first appeared on this earth. Fish also breathe oxygen. Oxygen is also used up in other ways. Why is it that our supply of oxygen was not used up long ago? You already know that trees and other green plants use carbon dioxide to make their food. They take in carbon dioxide from the air through their leaves. At the same time, they give off oxygen in return. In this way, the supply of oxygen in the air is constantly renewed.

OXYGEN—SUPPORTER OF BURNING

There would be no ordinary burning without oxygen. Water is used to put out fires because it covers the burning material so that the oxygen of the air cannot reach it. Water also cools the burning material below the point where it would ordinarily unite with oxygen. Most school fire extinguishers throw out CO_2 gas to blanket burning material from air. And that's why a person whose clothes are on fire should never run—his clothes burn more freely if more oxygen is brought into contact with them. Instead, he should be wrapped in a blanket or rug to smother the flames. A jar placed over a lighted candle illustrates the same thing. The candle soon goes out as the oxygen in the air in the jar is used up to the point where there is not enough to support burning.

WHAT ARE THE USES OF PURE OXYGEN?

Some substances, such as acetylene, combine so freely with pure oxygen that the hot flame produced is used to cut metals or to weld one metal to another. Oxyacetylene welding outfits are part of the equipment of large automobile repair shops. Large quantities of pure oxygen are used in this way.

At high altitudes the air is thin and contains less oxygen than air at sea level. Oxygen tanks are carried in military planes to supply the oxygen needed by crew members. Without this extra oxygen, the men would quickly lose consciousness. Oxygen tanks are also used in hospitals to help people who are so sick that they have difficulty in breathing. A covering, called an oxygen tent, into which flows air enriched with oxygen, is placed over them. With each breath they get far more oxygen than they get from ordinary air.

A LOOK AHEAD

You have now become acquainted with some of the chemicals of your environment. You have learned how some of them are used. But there are a great many materials in the earth's crust that are not found in everyone's back yard. You probably will not find such valuable ores as cinnabar, galena, or hematite, even within a great distance of your home. You probably will not find gold, silver, copper, or oil in your back yard. How some of these rarer substances are procured from the earth, treated, and used will be the subject of the next chapter, "The Wealth in the Earth's Crust."

GOING FURTHER

1 *Making a solution.* Dissolve a crystal of blue vitriol (copper sulfate) in one-half test tube of water. Now shake up a teaspoonful of soil in one-half test tube of water. Hold both test tubes up to the light. Which one is clear and transparent? Let both test tubes stand for five minutes. Which one has an even distribution of color? Which one settles on standing? From the results of the experiment make up a statement concerning the characteristics of a good solution.

2 *A chemical reaction in solution.* Stir a few small crystals of table salt and silver nitrate together on a paper. Is there any evidence of chemical change? Now dissolve a few crystals of table salt in one-half test tube of water. Do the same with a few crystals of silver nitrate in another test tube. Pour the solution from one test tube into the other. What evidence of chemical change is there? What do you conclude concerning the use chemists make of solutions in producing chemical reaction?

3 *Words are ideas.* Can you use these words in a sentence which will give their meaning? Use the glossary.

symbol	hard water	bacteria
ore	soft water	hematite
clay	oxidation	stalactite
granite	suspension	stalagmite
solution	distillation	galena
saturated solution		mineral

4 *Put on your thinking cap.*

1. We class as ores such substances as Al_2O_3 (aluminum oxide), Cu_2S (copper sulfide), $CaCO_3$ (calcium carbonate), SnO_2 (tin oxide), PbS (lead sulfide). Can you tell why?

2. What would you do to prove that a glass of clear water contains no dissolved substances? How would you make the water pure if you know beforehand that it is impure?

3. How would you increase the amount of potassium nitrate (KNO_3) you can dissolve in a certain amount of water at room temperature?

4. What would eventually happen:
   (*a*) to plants if there were no air?
   (*b*) to fish if there were no oxygen dissolved in water?
   (*c*) to people if there were no nitrogen in air?

5 *Test yourself.* In your notebook, complete the following sentences with a correct word or phrase. Do not mark this book.

1. CO_2 is the formula for one ...... of carbon dioxide in which there is one ...... of carbon and two ...... of oxygen.

2. The difference between a mineral and an ore is that we can get a useful ...... from an ore.

3. One ore of lead is called ....

4. Underground water containing ...... is responsible for the making of caves.

5. Water containing certain minerals is called ...... water. It can be made ...... by the addition of certain household materials.

6. Water containing all the dissolved substance it can hold at a certain temperature is called a ...... solution of that substance. The saturation point changes with the ....

7. Water that carries insoluble substances is called a ....

8. ...... is a method for making absolutely pure water.

9. When oxygen unites with any substance, the process is called ....

6 *Adding to your library.*

1. *The Boy Chemist* by A. Frederick Collins, the Odyssey Press, 1944. The history of chemistry, its importance today, and some interesting experiments you may perform in your laboratory.

2. *Wonder of Chemistry* by A. Frederick Collins, Thomas Y. Crowell Co., 1942. This book will acquaint you with some of the wonders of modern chemistry.

CHAPTER 15

THE WEALTH IN THE EARTH'S CRUST

No one knows exactly how ancient man discovered that some earth materials would yield metals which could be shaped into tools or weapons. Probably it was by accident. Perhaps the heat of a fire built upon some kind of ore produced a shiny metal that amazed and delighted the builders of the fire. At any rate, before any way of getting metals from their ores was discovered, man had only stone and bone for tools and weapons. Archaeologists (är′kē-ŏl′ō jĭsts), the scientists who study prehistoric man, divide the progress of civilization into periods or ages. Each period is marked by an increase in man's ability to use the materials in the earth's crust. What would be the first age? Archaeologists say: the Stone Age. Then, as man learned how to make bronze out of copper and tin, came the Bronze Age. Weapons, tools, and ornaments of bronze are still being dug up by archaeologists in the cities of ancient civilizations.

Though an improvement on stone, bronze was not hard enough for all the uses to which it was put. The Iron Age arrived when man found a way of getting this harder metal from its ore and working it into tools. Today we live in an age of steel, which is more useful in many ways than iron.

Have we traveled fast? No—only as fast as man has found and adapted to his use the materials beneath his feet. In this chapter, you will discover how much modern civilization depends upon man's increasing knowledge of the uses of metals. You will see how important are the deposits of coal, petroleum, and the other materials in the earth's crust.

METALS AND THEIR ALLOYS

There are many highly important metals without which modern civilization would be crippled. Iron is one; copper is another. Then there are zinc, tin, aluminum, magnesium, lead, manganese, tungsten, chromium, vanadium, nickel—in all about two dozen metal elements that we use in our daily life. Most metals like nickel, lead, tin, and gold are mined by sinking deep shafts and by following the veins of

176 *Strip mining of iron ore (hematite). Note how terraces are built as the ore is mined. Can you figure out why terraces are necessary?* (*Bethlehem Steel Company*)

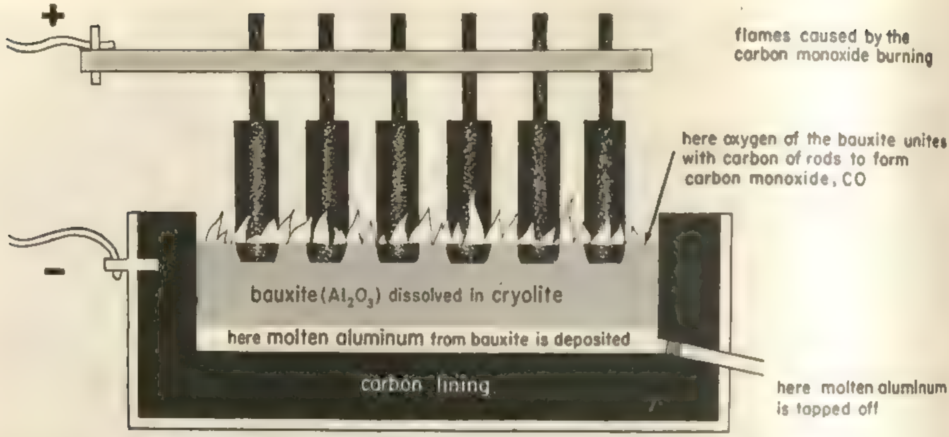
ore through tunnels leading from the shafts. There are tin mines in Great Britain that have been worked for 2,000 years with tunnels that run for miles beneath the ocean bed. There are gold mines in Ontario, Canada, over a mile deep, with miles of tunnels extending from the central shaft. Such mining is called *deep mining*.

Mining is less expensive and less difficult when the bed of ore exists near the earth's surface. Then the surface earth can be stripped off and the ore loaded into cars or trucks and sent to the smelter. Such mining is called *strip mining*. Iron ore is mined by this method in the Mesabi Range in Minnesota (Fig. 176). Veins of high-grade iron ore in Brazil, in Australia, and today in Canada, are being stripped for the world's use.

Coal is mined by both the deep and strip methods because layers or veins of coal are found far underneath the earth's surface as well as on or near the surface. So much coal has been taken from deep mines in eastern Pennsylvania that when the mine is abandoned and the pillars supporting the earth are removed, the surface of the earth settles into the tunnels, sometimes destroying parts of towns and villages.

SEEK AND YOU WILL FIND

Perhaps that was the thought young Charles Hall had in mind one morning in the year 1886. Certainly he had been seeking long enough. He had been



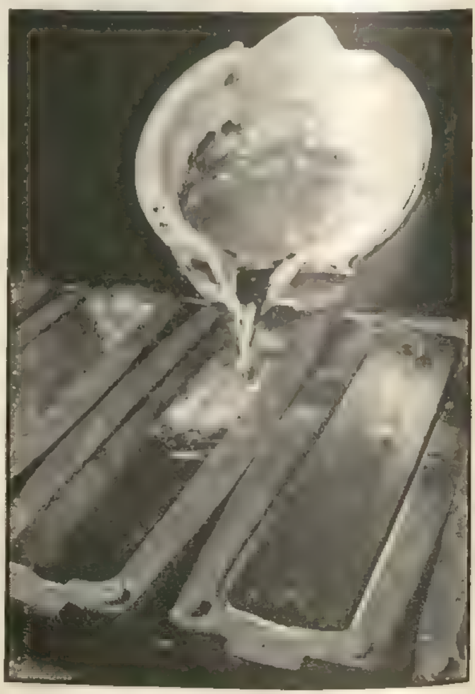
177 *Using electric energy to produce aluminum. Bauxite, the ore of aluminum, must be dissolved in cryolite, another aluminum ore.*

patient. He had been thorough. Now at last he thought he had found what he sought.

On this particular morning, Charles Hall with his sister, Julia, was standing before a crude electric furnace in his father's woodshed in Oberlin, Ohio. Hall closed a switch. Into the bottom of a carbon-lined frying pan trickled a thin stream of silvery-white, molten aluminum. When the current was shut off, the aluminum cooled quickly into a few pellets. These balls of aluminum, the first to be made in America, are called the jewels of the vast aluminum industry that now exists, thanks to Charles Hall.

Charles Hall was the first to make aluminum cheaply from bauxite, an ore of aluminum. Although aluminum is one of the more abundant elements found in ordinary clay, it is only from bauxite that it can be produced commercially (Fig. 177). Bauxite is made up of atoms of aluminum and oxygen (Al_2O_3). Hall separated the oxygen from the aluminum by using the energy of electricity. Before Hall discovered how to get aluminum from its ore, aluminum cost $542 a pound. Today, aluminum sells for about 15 cents a pound.

The process of getting a metal from its ore and preparing it for use is called



178 *Pouring molten aluminum to make bars of the metal. (Aluminum Company of America)*

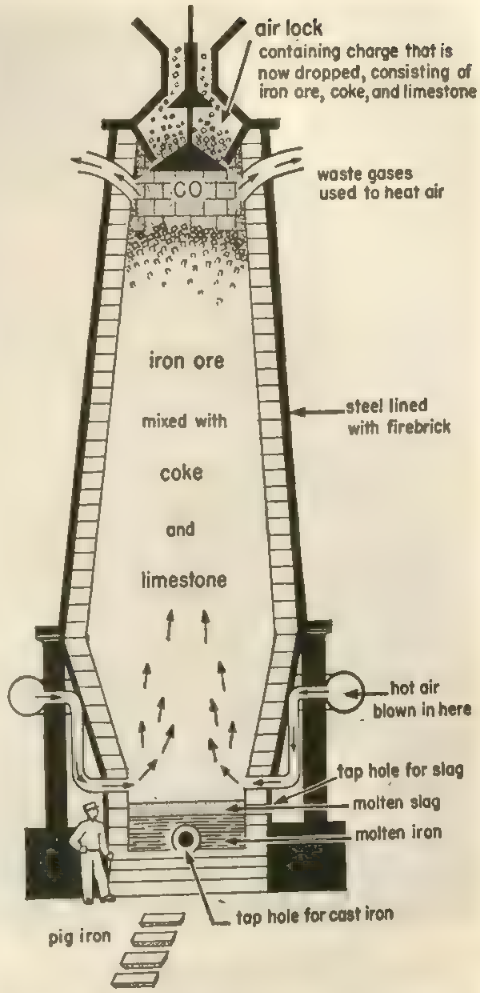
metallurgy (mĕt′'l ûr′jĭ). Charles Hall's process of getting aluminum from the ore bauxite is called the metallurgy of aluminum (Fig. 178).

THE METALLURGY OF IRON

The most important and useful metal in the world today is iron. Far more important than gold or silver or platinum, iron is necessary for the world's work. Iron is used in making steel. Without iron or steel, all manufacturing plants would eventually close down. We would have to go back to the Bronze Age, as far as heavy tools and machinery are concerned.

To get iron from iron ore, a tall furnace 100 feet high is erected and lined with firebrick (Fig. 179). It is called a blast furnace because blasts of very hot air are blown in at the bottom. Iron ore, coke (from coal), and limestone are put in through an air lock at the top. The carbon of the coke combines with the oxygen of the iron ore (Fe_2O_3) and molten iron is released. The iron then sinks to the very bottom of the furnace. Meanwhile the limestone unites with the impurities in the ore, mostly sand, forming a liquid "slag." The slag and the molten liquid iron are tapped off at two separate holes, the slag above the iron. Finally, the iron is solidified in bars called "pigs." Once started, a blast furnace is operated continuously by adding more charges of ore, coke, and limestone. If shut down, a blast furnace takes some time to get into operation again because it must be reheated to the high temperature at which iron melts.

Pig iron may be melted into molds or different shapes to form automobile engine blocks, stoves, bases for heavy machinery, and other articles where great rigidity is required. Such iron, called cast iron, will not stand bending or heavy shocks or blows.



179 *In the blast furnace superheated air melts the charge—iron ore, coke, and limestone—to produce cast iron. Molten iron is tapped from the bottom and is cast into bars called "pigs." The lighter molten slag, containing impurities, is drawn off above the molten iron.*

STEEL, THE BACKBONE OF INDUSTRY

There is no other man-made material so strong or so tough as the

180

A Bessemer Converter making steel. Note the flames caused by the burning of impurities in pig iron. (Bethlehem Steel Company)

different kinds of steel produced today. Steel may be made into various shapes and sizes, with the strength of cast iron but without its brittleness. Steel may be rolled, red-hot, and formed into steel rails for railroads. By continuous rolling, it may also be made into strips for the making of tin cans. It may be welded into girders for bridges. It may be woven into huge metal cables. It may be made into armor plates for battleships. It may be forged into tools of industry, engines of factories, automobiles, and trucks. From a watch spring or pen point to a locomotive, you will find steel playing its part in your everyday life.

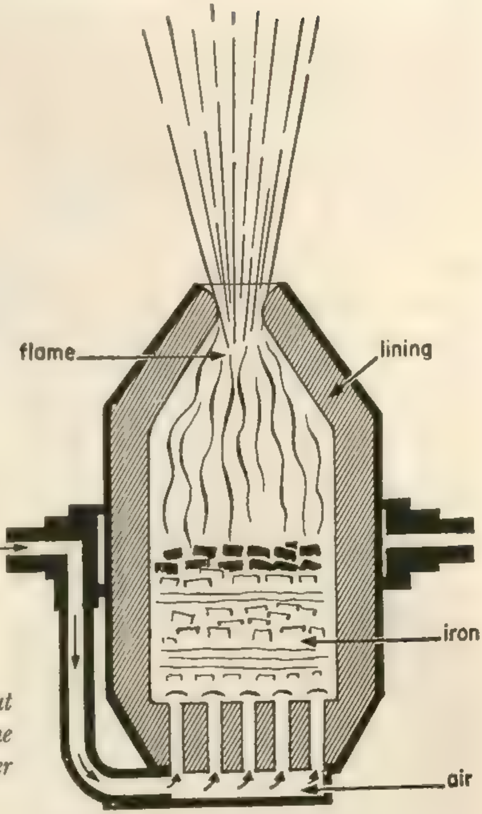
The first step in making steel is the removal of the impurities from pig iron. The first steel was made by William Bessemer in England, less than 100 years ago. He designed what is now known as the Bessemer Converter (Figs. 180 and 181). Blasts of cold air blown through the molten pig iron burn out most of the carbon, phosphorus, and other impurities. After about ten minutes, the air is shut off and carefully measured amounts of manganese and carbon are added. The molten steel is then poured out and another charge is inserted. Most low-grade steel is produced by this process.

Higher-grade steels are those in

which the impurities are more carefully controlled. This can be done in an open-hearth furnace (Fig. 182). First, all the impurities are burned out very carefully. Second, the amounts of manganese and carbon are measured most carefully before they are added to the molten iron metal.

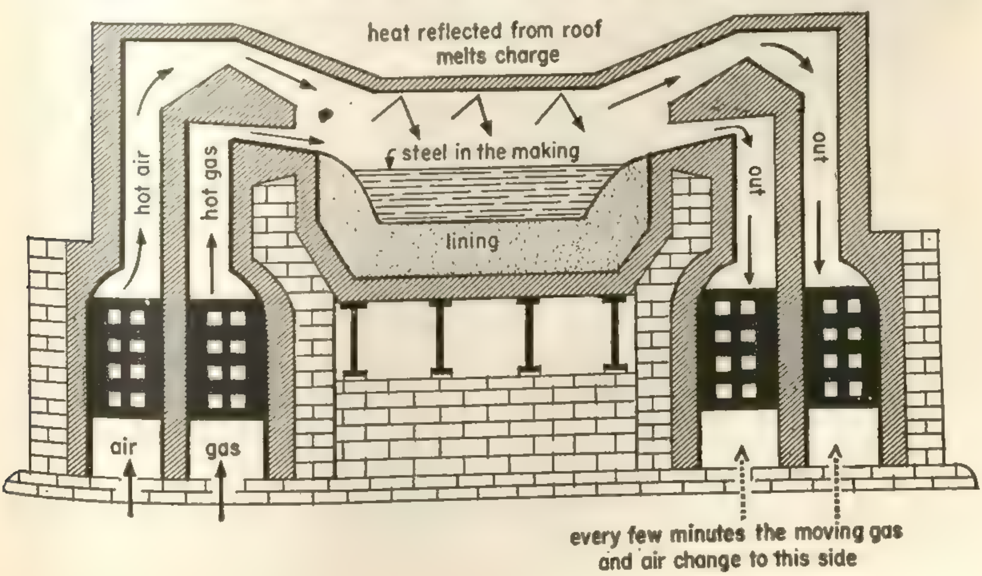
MAN-MADE METALS

While there are but relatively few metals that find their way into everyday use in the pure state, there are literally hundreds of different metals called alloys. These can be made by melting two or more metals together. An alloy is a mixture of metals in which each metal dissolves into the other. In general, the properties of alloys are



181
Air blasted through molten iron burns out most of the impurities. Why does a flame shoot out of the mouth of the Bessemer Converter?

182 *In the open-hearth furnace high-grade steel is made. Heat reflected from blasts of burning gas and air melts the steel. Thus impurities are carefully burned out.*



very different from the properties of the metals of which they are made. For instance, in many cases they are harder. Today we would find it very difficult—if not impossible—to have many comforts of modern civilization without the use of alloys.

ALLOYS

There are many different kinds of alloys. Steel alloys are those in which different metals are dissolved in steel. Thus we can make alloys of desired strength for a particular use. When about 4 per cent of nickel is added to steel, the alloy is tough and resists rusting. Gun barrels, armor plate, as well as bridge girders are made of nickel-steel alloy.

Manganese dissolved in steel makes an alloy that is hard and resistant to blows. This alloy is used in railroad switches, office safes, and heavy road machinery. Silicon alloyed with steel produces an acidproof metal used in making waste pipes for chemical plants. Stainless steel used in sink tops, cutlery, and wherever rustproof steel is necessary, is made by alloying nickel and chromium with steel.

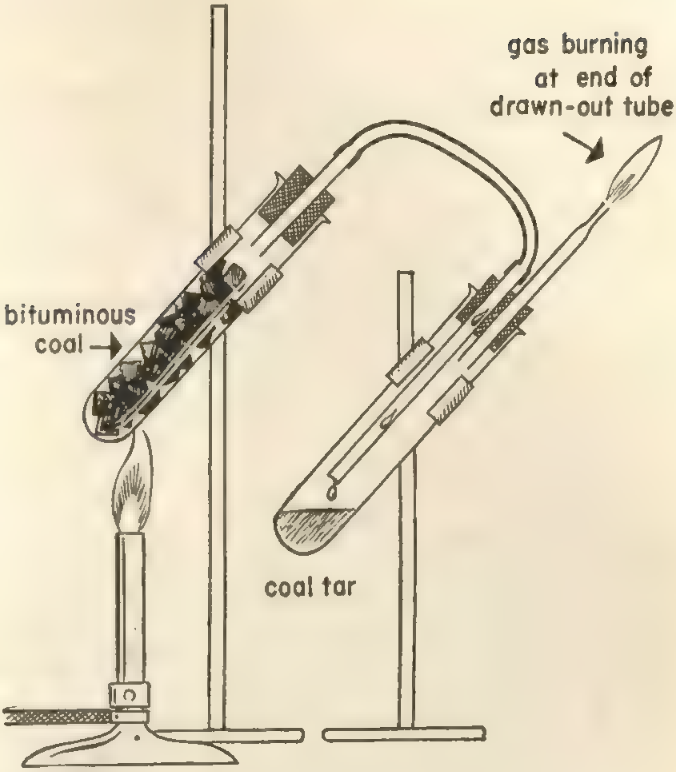
Alloys can be made of other metals. Perhaps the oldest alloy of this type is bronze, made of copper and tin. It is easily shaped and does not rust. Today it is used in coins, ship fittings, statuary, and ornaments. Other common alloys, together with their composition and uses, are found in the table below.

The last two alloys, duralumin and dowmetal, combine great strength with light weight. The development of the modern airplane is due in part to these alloys. Likewise, other alloys of aluminum and magnesium have been made to meet the growing demands of the modern aviation industry. No doubt the future will see greater use of light metal alloys in everyday living.

COAL AND PETROLEUM

You have learned that steel is the backbone of industry. But in order to make steel, you must have iron. In order to make iron, you must have coke. In order to make coke, you must have coal. It is like the lines from the old jingle: "For want of a nail the shoe was lost. For want of a shoe the horse was lost. For want of a horse the rider was lost. For want of a rider the battle was lost." And if you apply this idea to coal, you will find it the nail upon which modern industrial civilization depends.

Common Name	Composition	Use
brass	copper and zinc	water pipes, hardware
Babbitt metal	copper, antimony, tin	engine bearings
type metal	lead, antimony, tin	type for printing
German silver	copper, zinc, nickel	tableware
Wood's metal	bismuth, lead, tin, cadmium	low-melting alloy plugs in fire doors, oil storage tank valves, and automatic fire extinguishers in factories, public buildings, schools
duralumin	aluminum, copper	airplane covering and framework
dowmetal	magnesium, aluminum	airplane parts, forgings, wings



183
Bituminous or soft coal when heated produces illuminating gas and valuable by-products, such as coal tar and coke.

COAL—THE BACKBONE OF THE NATION

The mining of coal is one of the most important operations in the world. Without coal most trains would not run, factories would shut down, and cities and towns would be without gas, electricity, and power. Moreover, we would soon be without many medicines, dyes, and countless other products that are made from coal.

Coal is found in every geographical zone in the world, frigid as well as tropical. It was formed early in the earth's history from dead plants which were subjected to great pressures and high temperatures. Growing and dying, layer after layer of these plants became pressed together by changes in the earth's crust. Why do we know that there was once tropical growth near the North and South Poles? Simply because coal has been found in those regions, and coal is made only from dead plants which once grew luxuriantly.

DIFFERENT KINDS OF COAL

The most useful coal for industry is *bituminous* (bĭ tū′mĭ nŭs) or soft coal. To see why, take a test tube and fill it half-full of small pieces of bituminous coal. Fit a one-hole stopper with a delivery tube to this test tube (Fig. 183). Pass the end of the delivery tube through one of the holes in a two-hole rubber stopper. In the other hole place a piece of glass tubing, one end of which has been drawn out to a narrow opening. Fit this stopper into another test tube. Your apparatus should look like that in Fig. 183. Heat the test tube containing the soft coal. After two minutes

touch a lighted match to the gas coming from the drawn-out end of the glass tubing. It bursts into flame. Continue heating until the flame disappears. Examine the yellowish-brown material in the bottom of the second test tube. Take your apparatus apart and examine the material left from the coal in the first test tube. What does it look like?

Here is what you have done. You have, on a small scale, entered the public utilities business. You took soft coal and heated it without any air present. (You drove out the air in the test tube by heating). The soft coal then gave out a gas—like the gas you burn in a gas stove. That gas you lighted with a match.

The material at the bottom of the first test tube is coke, which is used for heating homes and for making steel. The liquid in the bottom of the second test tube is coal tar. From coal tar are made many of the dyes, drugs, perfumes, and food flavors used today.

Soft coal is very useful to many public utilities companies, isn't it? But that is not the whole story. Energy from soft coal runs engines and factories and makes electricity. No matter where you go, you will find soft coal also being used to heat public buildings and many homes.

Another kind of coal, used mainly for heating homes, is called *anthracite* (ăn′thrȧ sīt) or hard coal. Anthracite coal burns with less ash and soot than does bituminous coal and is favored by many homeowners because of this fact. Another type of coal is peat, which is burned in many sections of the world where there is a shortage of bituminous and anthracite coal. The United States is fortunate in possessing large deposits of the best grades of coal—even though it uses 500,000,000 tons a year. It is estimated that we have supplies sufficient to last more than 3,000 years at current rate of use.

PETROLEUM—THE LIFEBLOOD OF A NATION

From time immemorial, man has wanted to go faster than he could walk. Man's ability to travel at modern speeds depends on petroleum oil.

About three-fourths of the world's petroleum is used for transportation—to drive and lubricate automobiles, steamships, airplanes, railroad trains, trucks, busses, and countless machines that help man do his daily work faster and cheaper than with any other fuel.

The other one-fourth of the world's petroleum is used for making kerosene for lighting, for heating homes, for making asphalt, rubber, wax, vaseline, antifreeze, insect sprays, linoleum, medicines, plastics, and innumerable other items. Do you wonder that petroleum is called the lifeblood of the nation?

THE OIL REGIONS OF THE WORLD

Looking at the map (Fig. 184), can you believe that the shaded parts, covering a large part of North America, South America, Europe, and Asia were once beds of great, ancient seas? But they were. Geologists have found fossils of ancient sea life embedded in the rocks of these areas. Petroleum has been discovered in parts of these areas, particularly near the eastern end of the Mediterranean Sea and the lands surrounding the Caribbean Sea, the East Indies, and lands on the edge of the Arctic Ocean. The richest petroleum regions are in the Mediterranean and Caribbean areas.

Why is petroleum, which is composed of carbon and hydrogen, found in the beds of ancient seas? Scientists know that petroleum was formed by the slow decay of swamp and ocean animals and plants that were buried millions of

184 *The shaded areas in the map, once beds of ancient seas, are possible oil-producing regions of the future. Today the United States is the leading nation in the production of petroleum.*

185 *Here a "shot hole" is being drilled 150 feet into the earth, where dynamite will be exploded. The returning echoes enable scientists to plot the shape of rock formations thousands of feet down.* (*Shell Oil Company*)

years ago under sediment. This decayed matter under enormous pressure was changed into gas and petroleum which were forced into pockets below the earth's surface. Some of these beds now exist thousands of feet below the surface of the earth's crust.

SEARCHING FOR OIL

Strange as it may seem, a doodlebugger is not a person who makes aimless drawings on paper while thinking of something else. It was a name applied in the early days of the oil industry to men who claimed they could locate pools of oil beneath the earth.

To most people there was always something mysterious about the way Nature had buried petroleum far down in the earth's crust. Some men claimed they could locate the oil with a forked stick. They carried the forked stick before them as they walked over an area being studied. Whenever the stick turned point down toward the ground, they claimed, it pointed to a pool of oil. Others claimed they could smell oil. Others said the presence of oil so affected their joints that they would jump about madly and painfully when they felt oil beneath their feet. Still others claimed oil attracted them like a magnet so that they left tracks twice as deep over land covering a pool of oil. Strange to relate, by good fortune some of these doodlebuggers happened to guess right. All these methods, of course, were based on guesswork, not on scientific knowledge.

Today geologists have worked out a surer method of locating oil. Dynamite is exploded over an area where oil is expected to be found (Figs. 185 and 186). The returning echoes from rock formations far underneath the earth's surface are recorded by sensitive instruments. The shape of the formations is plotted. When the echoes indicate a dome where there is likely to be oil, the portion closest to the surface is located and a well is drilled. A dome of rock is formed by a wrinkling of the earth's surface (Fig. 186). In oil-bearing regions this dome is usually composed of hard rock, under which is a large mass of porous rock or sand filled with petroleum and gas, or with gas alone.

When a well is drilled through the dome, several things may happen. First, a pocket of wet natural gas may be found. After extracting gasoline from this gas, operators pipe the gas to distant cities and towns, where it may be used for heating and cooking. Second, the pressure of gas on the petroleum under the dome may push the petroleum up the pipe with considerable force. If the

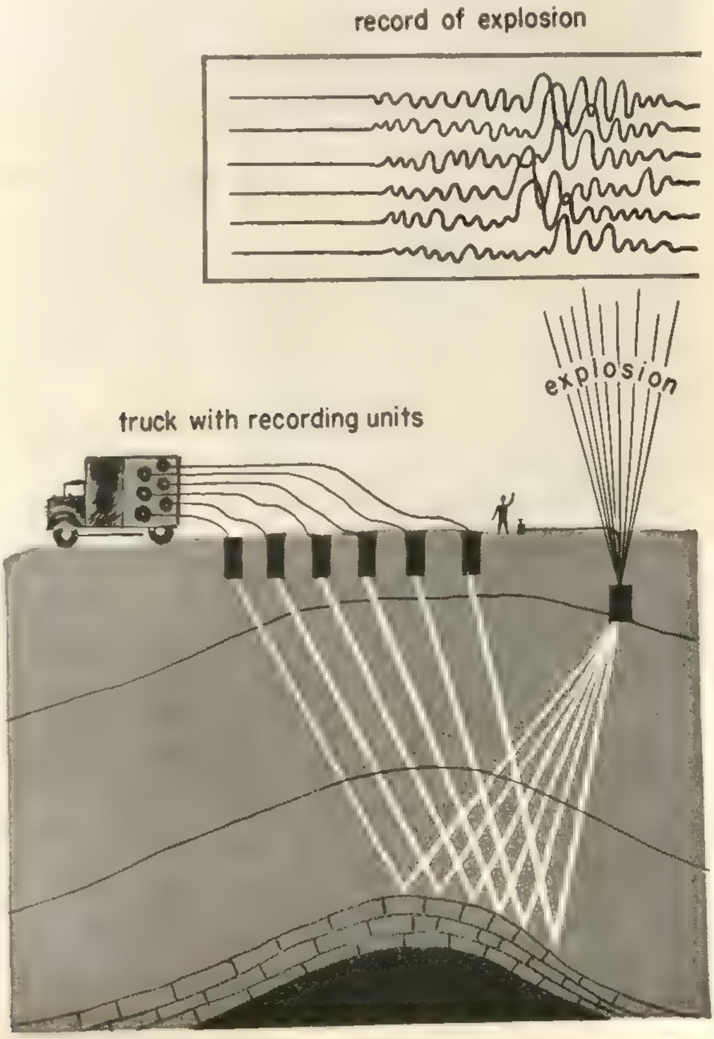
oil gushes out of a newly drilled hole, the hole is capped and the flow can be regulated at the surface. Third, the petroleum may rise only part way up the pipe and may have to be pumped the rest of the way. Fourth—and this happens many times—the well may be dry and yield nothing.

IMPORTANT MINERALS

Sometimes the search for petroleum has led to the discovery of other natural resources.

SULFUR—A MEASURE OF WEALTH

Would you have been as disappointed as were the prospectors who drilled for oil in Louisiana, near the Gulf of Mexico, about 60 years ago? Instead of oil they discovered sulfur. It was 500 feet below the surface. It could not be mined like coal because drill samples showed quicksand above the sulfur. The prospectors gave up in disgust. But not Herman Frasch (fräsh), who heard about these beds of sulfur in 1891. He figured that if he could not go down to the sulfur, he would

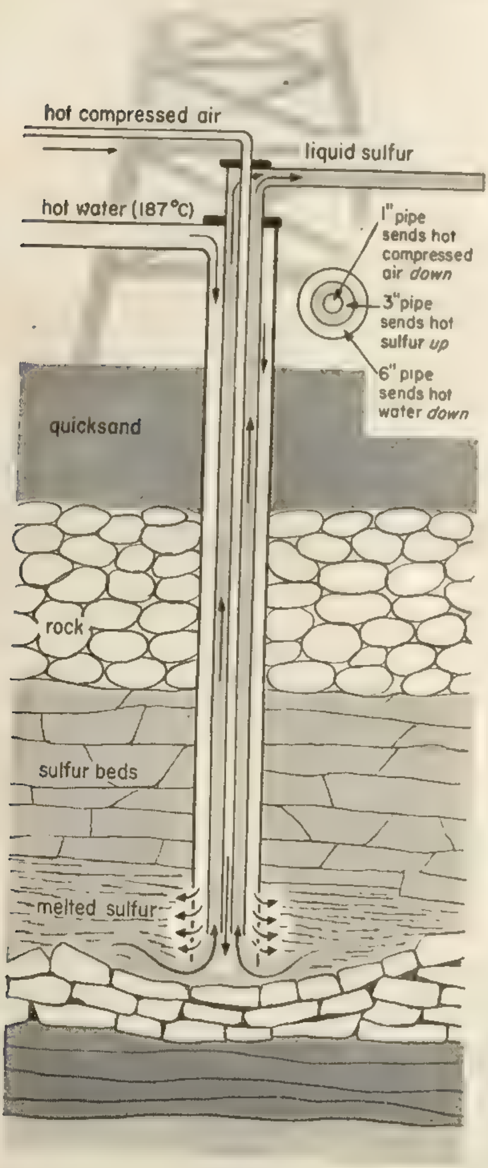


186

How scientists use echoes from exploding dynamite to detect the presence of an oil dome far underneath the earth's surface. The explosion sends sound waves downward. The rock formation reflects them upward to the surface. The pattern of the returning waves on the record of explosion shows where the dome is located.

make the sulfur come up to him. Look closely at Fig. 187. Don't you think that Herman Frasch had a good idea? Before Frasch developed this idea, we had to get sulfur from foreign countries. Today all sulfur in this country comes from these wells.

Sulfur is a yellow element, hard and crystalline at room temperature, but may be easily melted. It occurs in the free state in many regions of the world. Because of the importance of sulfur to industry, it is said that the wealth of a nation can be measured by the amount of sulfur it uses. The United States uses over two million tons each year in making sulfuric acid, matches, paper, plastics, orchard sprays, ointments, and vulcanized rubber.



187 *Herman Frasch invented this process of getting pure sulfur from the earth's storehouse. Superheated water goes down the outside (6-inch) pipe and melts the sulfur. Hot, compressed air goes down the central (1-inch) pipe and forces the liquid sulfur up through the middle (3-inch) pipe.*

SALT—A BASIC MINERAL

"That will cost you half a pound of salt." You may not have heard this expression, but you would have heard it had you lived in Kentucky in Daniel Boone's time; or in Abyssinia or Tibet even today. The expression, "You are not worth your salt," comes from the fact that salt is such an important mineral. In the past, governments have placed taxes on its production and use; and people have used it for money.

Salt ($NaCl$) is a food necessary to life. It is used also in making many other necessary compounds. In your home, baking soda and washing soda are products made by the chemical industry from salt.

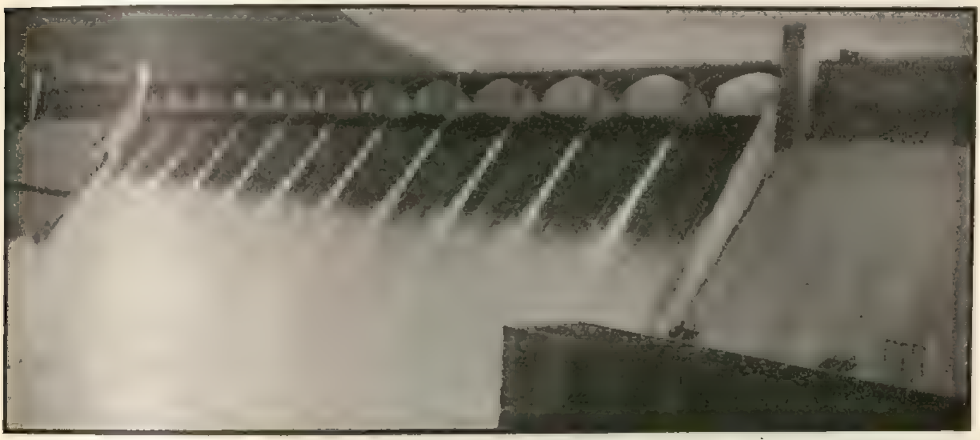
In most places, salt is mined like sulfur. Beds of salt below the earth's surface are dissolved in water which is sent down one pipe and pumped up through another. Then the water is evaporated, leaving the salt behind. Near Watkins Glen, New York, salt is mined by this deep method. In many parts of the world a great deal of impure salt is obtained from salt lakes and the ocean by evaporating the water.

LIMESTONE AND CEMENT

Without limestone no large modern building could be built. Limestone is a necessary ingredient in cement, and cement is essential in making foundations, floors, and supporting columns in modern buildings. To make cement, limestone is mixed with clay. This mixture is then heated and ground to a fine powder. In this form, it is sold to builders who use it to make concrete.

Concrete is made by mixing one part of cement with two to eight parts of sand and gravel or crushed rock. Water is added and the mixture is poured into forms where it hardens. Concrete may be reinforced. When it is used for roads, walls, and floors of buildings or for dams, it is reinforced by pouring the concrete around steel rods. Reinforced concrete is hundreds of times stronger than ordinary concrete. A simple demonstration will show why.

Mix enough concrete (one part of cement with eight parts of gravel) and enough water to make a workable mixture to fill two shallow boxes similar to the flats used by florists. Embed a layer of chicken wire or window-screen wire in the soft mixture in one box when it is half-full. Fill the remainder of the box with the mixture. Now fill the second box with the mixture too, but omit the screen wire. After the concrete has "set," remove the slab of concrete from each box. Suspend each slab by placing its ends on some bricks or pieces of wood. Step upon the middle of each slab (Fig. 188). What do you discover concerning the strength of the reinforced concrete?



188 *Reinforced concrete makes possible huge dams like this one at Grand Coulee, Washington.*

A fairly good idea of the amount of concrete used in the United States may be gained from the fact that over 175,000,000 barrels of cement are produced here yearly.

CLAY AND SAND

For centuries men have known how to make bricks, tile, and earthenware vessels from clay. Have you ever heard of the potter's wheel (Fig. 189)? As it turns, a skillful potter can fashion beautiful vases by molding the wet clay. Baked in an oven, painted, and glazed, or treated with a colored glaze, these vessels are in constant demand today. The plate you eat from, the cups and saucers and other dishes you use probably are made from pressed

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As the potter's wheel turns, the wet clay vase is shaped by a skillful worker. (N.Y. State College of Ceramics, Alfred, N.Y.)

clay formed on the potter's wheel or its modern equivalent.

The glasses you drink from, the dishes used in baking, the windowpanes you see through, the glass blocks used in building are made by different methods. But sand is the common material used in each method. Ordinary window glass is made by melting sand with calcium carbonate and sodium carbonate. The liquid mixture is first blown out into circular, uneven sheets. These sheets are flattened and cooled slowly to avoid strains in the glass. Then the sheets are cut into standard sizes (Fig. 190).

Plate glass is made by rolling the molten glass into a sheet upon a metal table. The sheet is then cooled slowly and ground and polished. Plate glass does not have the uneven, wavy lines of window glass.

Shatterproof glass is made by joining two pieces of plate glass together with a sheet of transparent plastic glued between them. If an automobile windshield is hit, the plastic keeps the glass from flying and cutting the occupants of the car.

Glass building blocks are made by molding two halves of ordinary glass and melting the two halves together. This process leaves the center hollow. Glass blocks let light pass through, but

you cannot see through them. They are useful for giving more light to schools, factories, and homes.

Glass is one of the most useful substances in the world. Millions of bottles are made each year by pressing hot glass into molds. The chemist depends upon blown and molded glassware for his work. Spun into fine threads, glass is used as glass wool for insulating homes. Even finer threads of glass may be colored and woven into waterproof, fireproof, nonfading cloth. Glass has indeed become a universal servant.

SAVING OUR MINERAL RESOURCES

A great part of the wealth of a nation lies in its natural resources. Next to the productive power of its human resources, the richness and variety of its natural resources determine its strength and wealth. The United States is the wealthiest nation in the world partly because it has developed the richest natural resources of any nation. But it has also used them recklessly. Still it is not too late for us to conserve the remaining wealth in our natural resources bank.

CONSERVING COAL

Scientists estimate that the United States has enough coal resources to last at least 3,000 years. But this does not mean that we may mine and use coal wastefully. It costs a good deal of money to mine coal, and as the deposits near the earth's surface are exhausted the cost of mining will go up. Everyone who uses coal or things made with coal will be affected by these increased costs.

The people of Pennsylvania recognized these facts and in 1939 acted to preserve their great anthracite coal deposits. In that year they passed the Pennsylvania Commerce Act which permits miners and mineowners to sit down with the State Secretary of Mines and plan the mining of hard coal. Each Monday representatives of the union workers, the mineowners, and the Commonwealth of Pennsylvania meet to decide how much coal is to be

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Suction cups lift large sheets of glass onto a conveyor line. (Pittsburgh Plate Glass Company)

mined that week. With this kind of action, it is possible for the mineowners to plan their production. Waste is kept to a minimum, and the coal resources of Pennsylvania are carefully guarded.

For heating homes, running factories, and making electricity, coal ranks first as a fuel. In the past, over one-third of this heat from coal has gone up the chimneys doing no one any good. Today better methods of burning coal have been invented so that this loss is now cut in half. You yourself may have an automatic stoker for burning coal more completely in the furnace of your home. Industrial plants have found ways to use one pound of coal to do the work of three. Waste is checked by controls set in chimneys. Also, we will use less coal for heating and cooking by using electricity produced from water power. These and other methods about which you will read later are the modern ways of conserving our coal resources.

WHAT ARE WE DOING TO CONSERVE PETROLEUM?

You would be rightly startled if you saw in the morning paper next December 31 a headline stating—EIGHTY BILLION GALLONS OF OIL DISAPPEAR. That is over one and three-quarter billion barrels—the amount of petroleum produced in the United States in a recent year. Can we keep on at this rate without sometime coming to the end of our oil supply? Let's look at the facts.

Today our estimated known oil reserves are 21,000,000,000 barrels. At our present rate of use, we shall use all our known supply of oil from wells by 1961. But the reserves are not our only oil resources. In this country, we have over one and a half million square miles of land that might produce oil. Only one half of this area has been explored. Estimates made by geologists tell us we may expect to find in the future as much oil as we have produced in the past. That would mean another 50,000,000,000 barrels, which, added to our known resources, would give us enough petroleum for the next 35 or 40 years.

But that is not the entire story. Looking ahead, the great oil companies are now setting up plants for the production of oil from certain oil-containing rocks, known as oil shale. We have a great supply of these rocks. Oil may also be made from natural gas, of which we have billions of cubic feet left in the earth; from tar sands, of which Canada has great resources, and from coal, of which we have plenty still unmined. Recently scientists have been attempting to recover the oil which is to be found in the earth beneath the tidewaters. The areas along the ocean shores where the tide rises and falls are called the tidelands. A rich reserve of oil, called tideland oil, has been found in these areas. You will hear a great deal about tideland oil in the future.

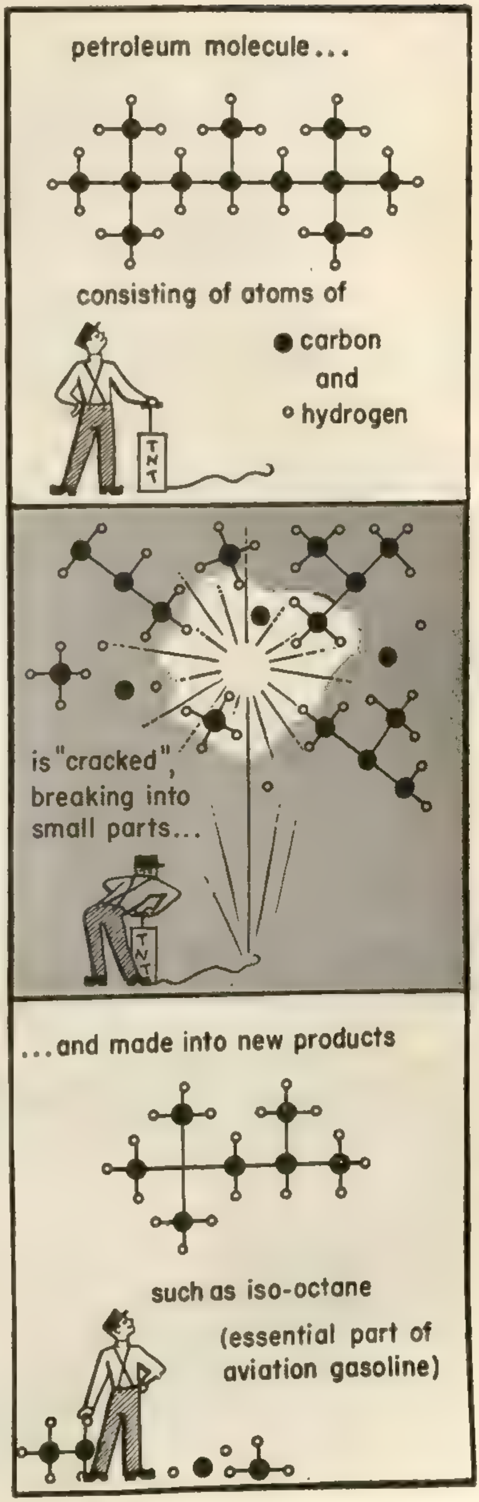
In the early days of the petroleum industry, men knew little about conservation and could see no need for it. It often happened that within one small area far too many wells might be drilled. With so many wells in one oil area, there was a great deal of waste. A few wells properly placed can bring a greater portion of the oil to the surface. In the early days, gushers, oil wells that blow oil a hundred or more feet into the air, were allowed to run unchecked for days and weeks. Billions of cubic feet of natural gas were allowed to spout into the air from gas wells—or were purposely set afire. We can no longer afford such waste.

Today, many states have oil conservation laws to govern the drilling of wells and the pumping of oil from them. The object of the oil conservation is to draw from the earth only what oil is necessary. New wells are being sunk and new fields are being explored for the future. But the day of the wasteful, uncontrolled gusher is past. By pumping gas into old wells, operators today bring all but about one-fifth of the underground pool to the surface. Formerly they left three-fourths in the ground. Furthermore, oil as well as gas wells are capped for future use. Both gas and oil from capped wells are carried thousands of miles by underground pipe lines, thus cutting transportation costs (Fig. 192).

Moreover, at the refineries, greater care is being used in making gasoline from petroleum. Much of today's gasoline is made through a process known as *cracking*. In cracking, the oils which boil at high temperature are heated under great pressure. This process causes the heavier molecules of oil to break down into the lighter molecules of gasoline. Thus the nation is now getting more gasoline from each barrel of oil than before. Indeed by the cracking process, we can now get more than one barrel of gasoline from one barrel of crude oil (Figs. 191 and 193). We are trying to conserve what petroleum we have now, and by exploration we are providing reserves for the future.

CONSERVING METALS

During the past ten years the ore supplies of the country have been used up more rapidly than ever before.

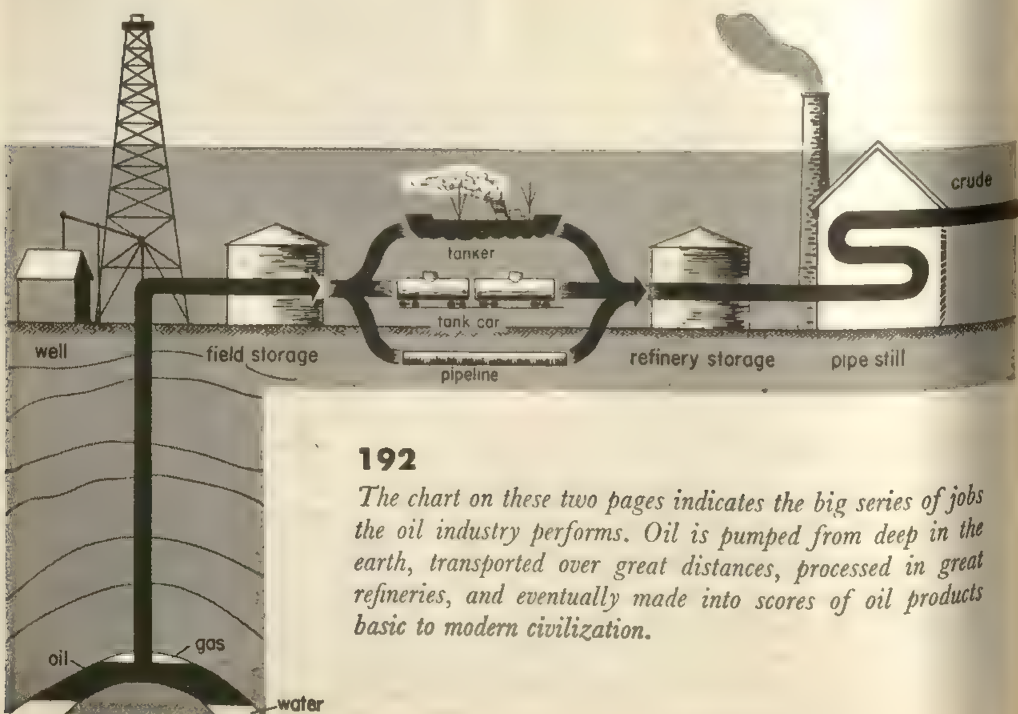


191 *Molecules of petroleum are "cracked," or heated under great pressure, to produce one-quarter of the gasoline used in the United States today.*

During World War II we learned from metal shortages that our resources are limited. Today, it is not a question of finding new supplies of rich iron, copper, lead, zinc, gold, or other ores. Perhaps we have found all the sources in this country. It is a question of conserving what we have. We also need better methods of using the poorer ores that still remain untouched. Some scientists estimate that our good iron ore in the Mesabi Range in northern Minnesota, from 50 to 60 per cent pure iron, may last for 30 years or so. It will not last as long as that if we use it up at the same rate as in the last ten years. During World War II nearly 90,000,000 tons of ore were shipped from Duluth down the Great Lakes each year. The prewar average was about half as much. We still have in Minnesota an almost inexhaustible supply of lower-grade iron ore, about 30 to 35 per cent pure iron. Science and industry are now hard at work to find an economical way of extracting the iron from this lower-grade ore. Meanwhile, great beds of iron ore have been discovered and are now being worked at Steep Rock, Canada, and in northern Labrador.

Our copper and lead, zinc, and other ores are practically in the same condition; that is, the richer sources are nearing exhaustion and we are seeking ways and means of using the poorer ores. We cannot supply our needs for other metals, such as tin, chromium, and tungsten. We have to import them from abroad.

Some metals, like iron, combine readily with oxygen in the presence of moisture. If left unprotected, these metals corrode. Corrosion often continues until the metal eventually crumbles. That is why steel bridges have to be painted



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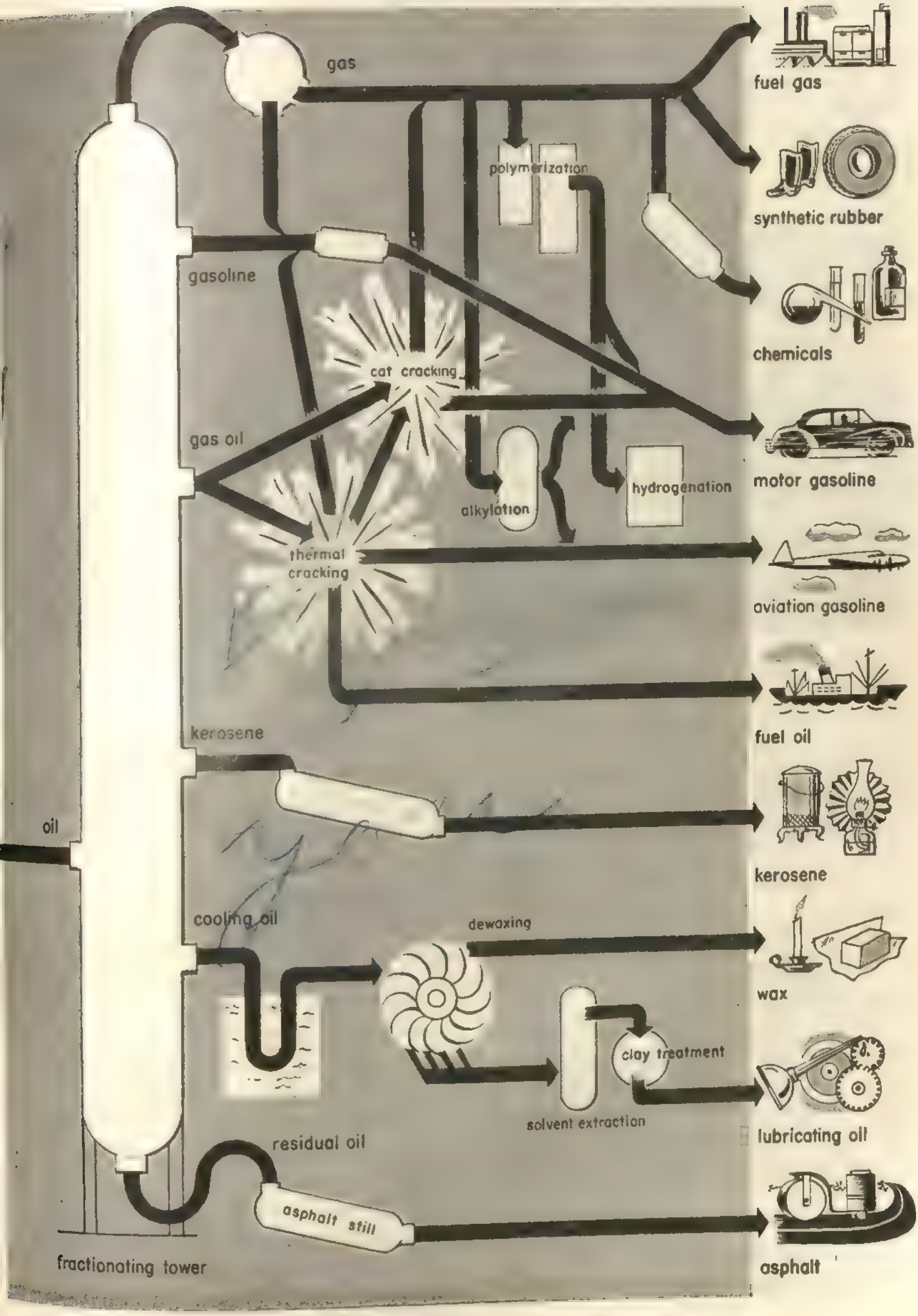
The chart on these two pages indicates the big series of jobs the oil industry performs. Oil is pumped from deep in the earth, transported over great distances, processed in great refineries, and eventually made into scores of oil products basic to modern civilization.


gas
fuel gas
polymerization
synthetic rubber
gasoline
chemicals
cat cracking
gas oil
motor gasoline
alkylation
hydrogenation
thermal cracking
aviation gasoline
fuel oil
kerosene
oil
kerosene
cooling oil
dewaxing
wax
clay treatment
solvent extraction
lubricating oil
residual oil
asphalt still
fractionating tower
asphalt

193 *Distillation and cracking processes at a large oil refinery. Can you see the distillation towers in the left background?* (*Standard Oil Co.* (*N.J.*))

every so often. Paint protects the surface of metals from rusting.

Coating with zinc is another form of protection given to iron. This process is called galvanizing. The zinc protects the iron for a long period of time. Still another way is to coat iron with tin—as in making tin cans. Only when the thin coating of tin is removed by wear or scratching does the can rust. Enameling and plating are other methods of protecting metals which rust. Some of your tableware may be silver-plated and so be protected. But if you have something made of iron or steel which you want to store, a coating with oil or grease will prevent rusting. By these methods some metals can be kept useful even when exposed constantly to air.

It would be impossible to list all the materials we need to conserve. The foregoing are merely examples. As you go on in your study of science, you will learn in greater detail just how we are conserving our other minerals.

Whatever the mineral, scientists are finding ways to make our own supplies go further. For instance, mineral wool, made from certain rocks, is being used for insulation instead of asbestos, which is somewhat limited in supply. Mineral wool is often used in furnace coverings, although its greatest use is in insulating walls and roofs of homes. The use of cement for concrete bridges and buildings saves both steel and wood. But even more than this, scientists are constantly discovering new products as

substitutes for those found on the earth. Many of these substitutes are improvements on materials found in the natural state.

IMPROVING ON NATURE

You must not think that improving on nature means becoming independent of our natural resources. This dependence on our natural resources is clearly shown in the making of artificial rubber. Even though we have made substitutes for natural rubber, the substitutes themselves are made from precious natural resources. For example, one kind of artificial rubber is made from substances found in petroleum.

RUBBER—A MODERN NECESSITY

It is said that more common articles are made of rubber than of any other single product in the world. Rubber is waterproof, elastic, and long-wearing. This makes it useful in countless ways. In your house, for example, how many things are made of rubber?

Raincoats, rubber overshoes, boots, sneakers, soles of shoes, wringer rolls, belts for the refrigerator and washer motors, insulation for electrical wiring, faucet washers, rings for fruit jars, rubber bands, and centers for baseballs are all rubber articles. These are a part of your daily life. Transportation by automobile, bus, truck, or even by bicycle would be difficult without rubber tires and tubes. In factories, rubber conveyor belts carry material, sometimes miles, from place to place. Rubber belts transfer power from drive shafts to machines. Rubber hose transmits water, gasoline, and air. Rubber is important for manufacturing telephone, telegraph, radio, and electrical equipment. There is scarcely a modern home that does not use rubber in one form or another.

WHAT IS RUBBER?

As you know, crude rubber is produced by rubber trees. The name "rubber" came from one of its first uses. In 1770, when it was found to be better than bread crumbs for erasing pen or pencil marks on paper, it was given the name "rubber" or "eraser." In 1833, the first articles manufactured from crude rubber were placed on the market. But they became sticky and melted in the summer's heat or grew hard and brittle in cold weather. Charles Goodyear, in 1839, found that combining sulfur with crude rubber remedied these defects. His process became known as vulcanizing. Vulcanized rubber articles resisted both heat and cold. Charles Goodyear's process is the basis of our rubber industry today.

Crude rubber is gathered as a liquid which is secured by making a cut in the bark of the tree. The liquid is collected in buckets as it drains from the tree. This liquid is heated into a solid substance known as latex (lā′tĕks) for shipment. It is treated by acid, dried, and rolled into sheets to become the natural, crude rubber of industry.

SYNTHETIC RUBBER

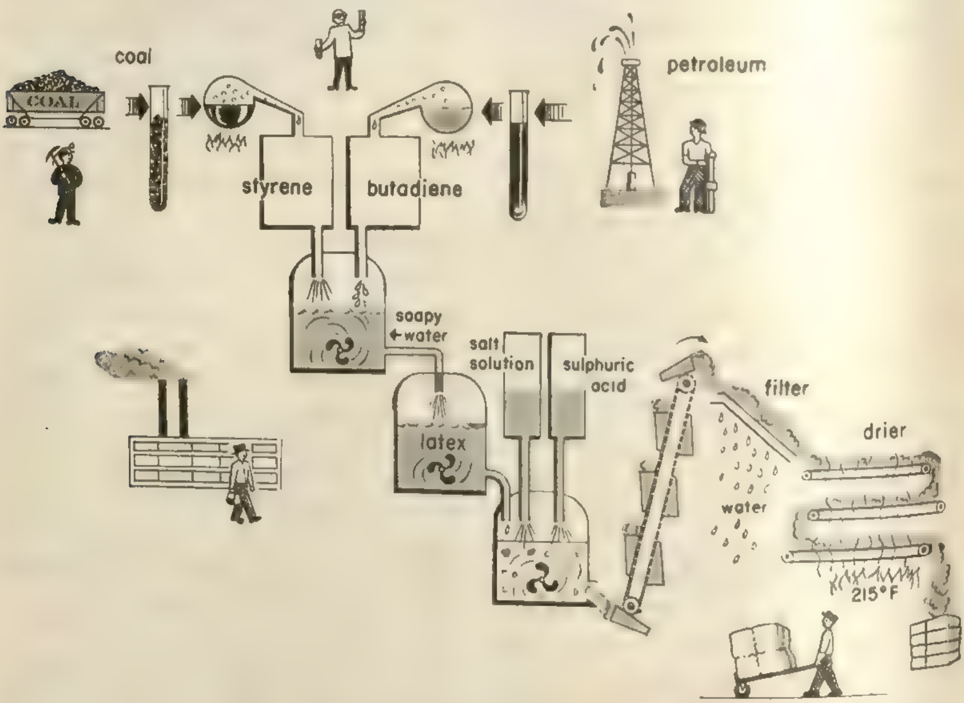
Many years ago, scientists experimented with other ways to get rubber besides gathering it from trees. Other plants were tried—dandelion, goldenrod, and guayule (gwä yōō′lā), a desert bush. None proved as useful as the rubber tree. But when supplies of crude rubber from the Far East were cut off early in World War II, scientists set feverishly to work. Already some synthetic or artifical rubber had been made from butadiene (bū′t*a* dī′ēn), a substance produced when petroleum is purified. When styrene (stī′rēn), which comes from coal, is mixed with butadiene, a substance like natural rubber

is produced. It looks and acts like natural latex. When thickened and dried, this synthetic latex is pressed into bales for shipment to rubber factories (Fig. 194).

Further work resulted in methods of making some 60 different kinds of synthetic rubber, not one of which exactly matches the natural product. However, in some ways the synthetic products are better. A synthetic, called Buna rubber, can withstand the action of oil, gasoline, and heat so well that it is used for gasoline piping at filling stations. Another artificial rubber called neoprene (nē′ō prēn) is used in industry for coating conveyor belts and for other heavy work because it can stand heat, chemicals, and wear. A still newer synthetic, butyl (bū′tĭl) rubber, seals air in tires ten times as long as natural rubber. This quality makes it valuable for inner tubes in tires, or for coating the inside of tires to eliminate use of inner tubes.

Another type of synthetic rubber, called silicone (sĭl′ĭ kōn) rubber, does what no other rubber can do. It will withstand the action of the strongest acids. It also retains its elastic properties at temperatures far below zero. Cabins of airplanes which fly in the cold upper air are therefore sealed with silicone.

Before World War II we imported about 700,000 tons of raw rubber each year. Today, we can make over 1,000,000 tons of synthetic rubber each year. For instance, 390,000 tons of butadiene were manufactured in 1946 from petroleum alone. There is no question, with the increased uses that are constantly being found for rubber and rubber products, that the future will make an even greater demand



194 *This diagram indicates the main steps in making synthetic rubber from petroleum and coal.*

upon our synthetic rubber industry than the past.

PLASTICS GROW UP

Synthetic rubber is only one of a whole string of man-made materials and products which science has delivered. The history of modern synthetic compounds dates back to the discovery of celluloid by John W. Hyatt, an Albany printer. Hyatt found that celluloid could be made by mixing the chemical, pyroxylin (pī rŏk′sĭ lĭn), with camphor. Easily molded, it used to be fashioned into detachable collars and cuffs for shirts, as well as into toilet sets and other articles. Because of this property, celluloid became known as a plastic. Today, as you will learn, plastics are an important part of our lives. One advantage of celluloid for collars was that a light sponging allowed the same collar to be used daily. It also had a serious disadvantage: A match or spark touched to a celluloid collar caused it to vanish instantly in a burst of flame.

The need for noninflammable plastic led L. H. Baekeland, a Belgian-American chemist, to experiment with a mixture of formaldehyde and carbolic acid. He got an easily molded plastic that is not affected by heat. It was given the name bakelite (bā′kĕ līt). Bakelite is used in making phonograph records, radio panel boards, noiseless gears, and pipestems. In its liquid form it is used in the manufacture of lasting varnishes and paints.

Today there are hundreds of kinds of plastics and thousands of uses for them. More and more they are taking the place of metal articles. Cast, molded, or pressed from the liquid or powder form, plastics can be made into sheets, rods, tubing, and blocks, or molded in those forms which can in turn be fashioned by machinery into many finished products. We can describe here only a few of the more important plastics today.

Lucite is a sparkling, transparent plastic that may be colored a variety of shades. Lucite is used in hairbrushes, lenses, or dials for clocks. Lucite may be made to glow in the dark. Lucite hatch covers in airplanes protect the pilot and give him full view above and on all sides (Fig. 195).

Polythene (pŏl′ĭ thēn) is one of the lightest plastics. It is insoluble in any liquid and is waterproof, flexible, and tough. It is used for watch straps, electric wire insulation, bottle containers, battery jars, shower curtains, and packaging.

Nylon is familiar to everyone now. In 1940, nylon yarn was woven into the first nylon stockings. In quick succession came nylon bristles for toothbrushes, hairbrushes and paintbrushes, replacing imported hog bristles. Molded into various forms, nylon makes tumblers, plates, combs, fasteners, self-locking nuts, tennis racket strings, and many other articles.

Cellophane is another widely used plastic. Item 15 of the United States Public Health Service Code reads: "All food and drink shall be so stored, displayed, and served as to be protected from dust, flies, vermin, pollution, handling, and other contamination." Cellophane wrappings for food and other articles provide this protection. Because it is transparent, cellophane also shows the kind, quality, and condition of the article inside. Cellophane is a plastic that has world-wide use.

Some plastics like cellophane are made from wood or cotton. Most, however, are products of coal, petroleum, air, and water. By constant research, chemistry has ushered us into

an age of plastics. Plastics are bound to have greater and greater use in our daily lives.

CLOTHES FROM WOOD, COAL, AIR, WATER, AND MILK

Whoever would think of making a modern dress from wood? Or stockings from coal, water, and air? Or a suit from milk? Chemists have succeeded in doing all these things.

Rayon, a substitute for silk, is made from wood fibers or short cotton fibers which are useless for making cotton thread. Nylon is made from certain coal products, water, and the gases in air. Liquid nylon is forced through tiny holes. It emerges in fine streams which solidify into nylon thread. Nylon thread is woven into stockings and cloth for dresses, curtains, and draperies. Because it is stronger than silk and does not lose its strength when stored for a long time, nylon cloth has become a real substitute for silk. Also, the strength of nylon has made it useful for fishing lines, towropes, and hawsers for ships and seaplanes.

Lanital (lăn′ĭ tăl) is a cloth that is much like rayon. However, lanital is made from a substance in skim milk, called casein (kā′sē ĭn). When casein is forced through tiny holes in a steel plate, it forms fibers that are like wool in appearance and strength. Although this wool-like material has not come into wide use, it has great possibilities for the future.

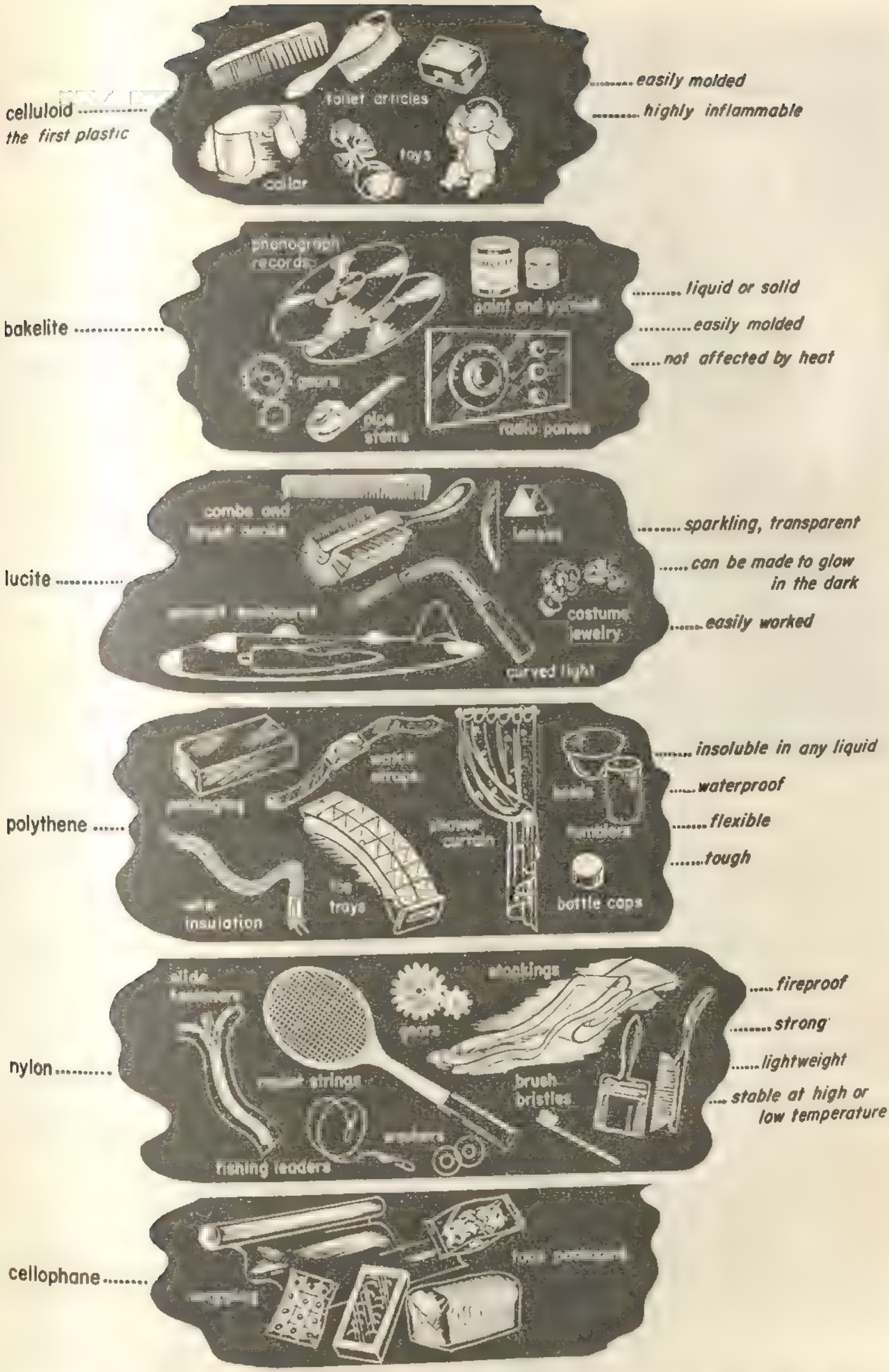
Whatever the cloth is, chemists have found ways to treat it to make it more pleasing to the eye or more lasting to wear. Cotton cloth, ordinarily a light yellow, is bleached by chlorine to a pure white. Silk is bleached by sulfur dioxide (SO_2). Cotton is given a silk-like sheen by treating it with sodium hydroxide. Cotton cloth is sanforized, or preshrunk, by steaming it while it is stretched upon wool. As the wool shrinks, the cotton shrinks. Laundering will not cause preshrunk cotton to shrink more than 1 per cent. Recently chemists have developed a substance which fireproofs cloth without changing its appearance.

ANY COLOR FOR THE ASKING

Plastics, textiles, paints, and enamels are supplied in a countless variety of colors, including shades and tints. How many colors can you notice around you as you read this chapter? How many tints in dresses or sweaters can you name? Don't be discouraged if you cannot name the exact shade or tint. Manufacturers try to make it easy by supplying trade names, such as robin's-egg blue for a particular shade of blue; coral pink for a particular shade of pink, and so on. There are over 100 shades for women's stockings alone!

Everyone has grown so accustomed to a colorful world that little thought is given to the long research that has made it possible. Formerly we got all our dyes from plants, animals, and some mineral compounds. Indigo, a blue dye, came from tropical plants. Cochineal, a red dye, came from the bodies of certain insects. Royal purple, formerly so expensive it could be used only by royalty, came from the bodies of certain Mediterranean snails. Today very few of these dyes are used. The same colors and thousands of others are produced from aniline, a coal-tar product (Fig. 196).

The start of the synthetic dye industry came when William Henry Perkin, a young English chemist, was experimenting with aniline in 1856. In the course of one of his experiments he produced a beautiful purple—similar to the royal purple—which he



195 *The use of plastics in various shapes and forms is part of your daily life. What are the characteristics of cellophane which make it useful?*

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Here a chemist is applying a yellow dye to a skein of cotton to make sure that the dyestuff is up to standard. (E. E. du Pont de Nemours and Co.)

called mauve. He found that cloth when colored by this mauve was permanently colored. The color could not be washed out.

From that time on, more and more dyes were made from aniline. Before World War I, Germany produced most of the dyes in the world. After dye imports were cut off during World War I, American chemists went to work. By 1918, we were manufacturing the important dyes, and today we make nearly all the dyes in common use.

New dyes are being made every day. But to be useful a dye must have a color pleasing to the eye. It should not weaken the cloth. It must be fast, that is, not affected by washing or sunlight. Most dyes are fixed in the fiber of the cloth by adding a compound like aluminum hydroxide.

SCIENCE IMPROVES LIVING CONDITIONS IN OTHER WAYS

You have learned that water is the universal solvent (p. 247). But there are some things like grease spots, perfume, perspiration, oil, and ink stains that water won't dissolve.

One of the important industries of this country is the dry cleaning industry. It is called dry cleaning because the substances used for cleaning cloth evaporate quickly. They take spots and stains away, leaving little or no odor. The substances are noninflammable and do not harm the fabric. They may be recovered after use to be used over and over again.

A good, noninflammable, cleaning agent that can be used safely in the home is carbon tetrachloride, commonly called carbona. Beware of using

gasoline or other inflammable solvents! Frequent accidents resulting in loss of life or property damage occur from use of substances like gasoline for cleaning in the home.

Soaps and soap powders are also synthetic cleaning agents. Some of these are manufactured from petroleum and coal. The soaps called detergents also have excellent cleaning properties.

The list is almost endless. Wherever you go, wherever you look, you will see man's inventiveness at work. He is using his brain to conserve his natural storehouse of minerals. He is beginning to mine the earth's crust wisely and well. But he goes further. He makes new kinds of rubber, new kinds of cloth, new dyes, new colors. In short, he improves on nature and adds to nature's infinite variety.

GOING FURTHER

1 *Lubricating metals.* Take two pennies and rub them together. Now place a drop of oil between the pennies and rub them together. Do you notice any difference? Bearings for automobiles and heavy machinery are made of alloys. Any place where one metal surface moves over another must be greased or oiled. If it were not for petroleum and the grades of lubricating oils that we procure from it, modern machinery could not function.

2 *Making mortar.* Fill a large beaker or basin one-quarter full of quicklime (CaO). Add enough water to cover the lime by half an inch. Is there any evidence of heat or of chemical action? Now stir in (with a spoon) enough sand and water to make a thick paste. Take two house bricks and spread a layer of this mixture on the surface of one. Place the other brick on this surface and with a stick wipe from the joint any excess mortar that is squeezed out. Let stand 48 hours. Are the two bricks joined together? Is the mortar hard?

You have made mortar by adding water and sand to quicklime. This mixture hardens on exposure to air, and thus it binds the bricks together. Do you know now how masons can build chimneys and brick houses?

3 *Testing plastics.* Send to a plastic manufacturing company for samples of various kinds. Test each one for the following:

1. Ability to be shaped (if a solid plastic) after being immersed in boiling water.
2. Inflammability (Place in contact with a flame).
3. Ability to transmit light.
4. Ability to transmit light with no reflection from the sides of a plastic tube (lucite).

4 *Dyeing cloth.* Make up solutions of at least three different colors of aniline dyes procured at a nearby store. Follow the directions on the packages. Now take three pieces of white cotton cloth and immerse them in the dyes. Remove and allow the pieces to dry. Expose the cloths to the sun for two days. Is there any noticeable change in the color? Now let water from a faucet run on the pieces for 15 minutes. Has any one of the colors washed out? What do you conclude about the qualities of a good dye?

5 *Cleaning clothing.* Rub some automobile grease or a vegetable oil on a piece of scrap silk or rayon. Pour a small amount of carbona (carbon tetrachloride) into a dish and rinse the piece of silk thoroughly in the liquid. Remove and allow to dry. What do you conclude as to the best way to clean grease from articles of clothing made of silk or rayon?

6 *Words are ideas.* Can you use these words in a sentence which will give their meaning? Use the glossary.

cracking petroleum	silicone rubber	cement
galvanizing	celluloid	cellophane
asbestos	lucite	mauve
vulcanizing	bakelite	magnesium
synthetic rubber	bituminous coal	chromium
cast iron	anthracite coal	manganese
alloy	mortar	metallurgy
concrete	plastic	slag
tungsten		limestone
		bauxite

7 *Put on your thinking cap.*

1. Why isn't all mining done by digging shafts down into the earth?

2. To be an industrial nation today, a nation must possess rich deposits of iron ore and coal. Explain.

3. Why is it necessary to conserve coal if we have an ample supply?

4. In what ways can you conserve fuel in your own home?

5. What will we do for gasoline and fuel oil when our present supply of petroleum is exhausted?

8 *Test yourself.* In your notebook, complete these sentences with a correct word or phrase. Do not mark this book.

1. Mining in the United States is done by the ...... and ...... methods.

2. The process of getting a metal from its ore is called the ...... of the ore.

3. Pig iron is made in the ...... furnace.

4. Two kinds of coal used mainly in the United States are ...... and ...... coal.

5. Plate glass is superior to ordinary glass because it does not have ...... lines.

6. Much of the gasoline produced from petroleum comes from a process known as ....

7. The rubber industry owes a great debt to ...... who invented the process of ...... rubber.

8. The search for a plastic that would not burn led scientists to the discovery of ....

9. Meat, fruit, and vegetables may be attractively displayed and protected by wrapping in ....

10. When a dye in cloth does not fade, it is known as a ...... dye.

11. Cleansing agents that are ...... should not be used in the home.

9 *Adding to your library.*

1. *America's Treasure* by W. Maxwell Reed, Harcourt, Brace, 1930. A detailed story of our natural resources.

2. *The Great Heritage* by Katherine B. Shippen, The Viking Press, 1947. Fascinating accounts of the natural wealth we possess—gold, coal, oil, iron.

3. *Boy's Book of Science and Construction* by Alfred P. Morgan, Lothrop, Lee, and Shepard, 1948. Chapter 2 is an interesting study of the fundamentals of chemistry, and gives a better appreciation of the fundamentals of plastics.

4. *This Chemical Age* by William Haynes, Knopf, 1942. This is the account of the production of man-made materials such as nylon and synthetic rubber.

CHEMISTRY AS A HOBBY

You have read the story of William Perkin, who pioneered in the making of synthetic dyes, and of Charles Hall, who discovered a cheap way of making aluminum. Both of these chemists were like thousands of others who became interested in chemistry when they were twelve, thirteen, or fourteen years old. In fact, William Perkin was only 17 when he made his first dye—mauve.

How do you make a start in chemis-

try? Probably you are already a chemist without realizing it. At least, it is fairly certain that there is one expert chemist in your family—your mother.

Every time your mother makes cookies, bakes a cake or biscuits, or makes preserves or jam, she is practicing chemistry; that is, she is producing chemical changes. A chemical change is produced when the original properties of a substance are changed by any means whatsoever. Thus, if you mix milk, baking powder, butter, flour, sugar, eggs, and flavoring, beat them up into a batter, and bake the batter into a fine cake, you won't be able to recognize any of the ingredients in the finished product. Likewise, a chemist carefully measures his ingredients, adds them together in a certain order or plan, and produces a product which is entirely different from any of the original ingredients. So if you wonder how you can make a start in chemistry, or if you think it might be difficult, just remember that if you are really interested in yourself, you are interested in chemistry.

CHEMISTRY AND YOU

Look around you—it makes no difference where you are. Either you see chemistry at work or you see what it has produced or has had a part in producing. If you are outdoors, remember that every living thing you see, from an ant to the tallest tree, is a chemical workshop. Yes, even you and the friend you may be walking with are chemical workshops in motion. Every living thing is constantly undergoing chemical changes—from photosynthesis in green plants to the digestion of food in the human body.

Chemistry has a part in the production of everything you wear and everything you use. It has had a part in making the dyes which color your clothes, the substances which clean them, and those which protect them against moths. It has tanned the leather in your shoes and it has made the stockings that you wear. It has helped to make the paper in this book and the ink with which it is printed. It has made the barrel of your fountain pen and mixed the graphite and clay in the lead of your pencil. Going further afield, chemistry has produced or has had a part in producing every metal article you come in contact with, from a steel rail to an aluminum dishpan, every drug from aspirin to penicillin, every dye from mauve to Congo red, every plastic from neoprene to lucite. In truth, chemistry is one of the most useful of all the sciences, and you cannot escape coming in contact with it or its products every day of your life.

DO YOU NEED A LABORATORY?

If you are now really interested in making a hobby of chemistry, you will need some sort of laboratory. Now do not be afraid of the word "laboratory." Your mother has one—her kitchen. And do not think that you must have a separate room. Perhaps you can share her kitchen, or you may find a place in the basement where there is running water and a sink. Access to gas or electricity for heating purposes is not essential because you can use an alcohol lamp if necessary.

Now as for equipment, here are the most essential items:

1. Two test tubes—at least one of pyrex glass. The pyrex glass test tube will withstand changes in heat and should be used for boiling liquids. You can get test tubes from a drugstore or from a scientific supply company.

2. A test tube holder. You can make it of wire. Use your own ingenuity. Use wire heavy enough to clasp the

test tube and long enough to provide a loop to act as a handle. Or you can buy a test tube holder from a scientific company.

3. Two beakers or glasses from the kitchen.

4. Litmus paper, red and blue, from a drugstore. Litmus paper is used to test for the presence of acids and bases. Blue litmus turns red when moistened with an acid. Red litmus turns blue when moistened with a base.

5. An alcohol lamp to use when you need heat.

And that is all! Of course, you can get more test tubes, glass tubing, rubber tubing, flasks, a ringstand, clamp and ring to support a flask, as well as scales to weigh out materials as you progress. But right here you need nothing more than the materials mentioned above.

Here is your first experiment. You can get the materials from your kitchen —as well as some other materials mentioned later.

TO SHOW HOW CAKE RISES

Baking powder is one of the most necessary ingredients of a cake. Have you ever heard someone say, "Look at that cake. It's fallen. Why did I forget to put in the baking powder?" And the cake, instead of being light, high, and fine-textured, is flat, heavy, and soggy —and has to be thrown away.

Baking powder contains three ingredients: sodium bicarbonate (baking soda), usually cream of tartar (acid potassium tartrate), and starch. The baking soda ($NaHCO_3$) and cream of tartar ($KHC_4H_4O_6$) react together when moisture is added to produce carbon dioxide (CO_2), a gas. This gas works evenly throughout the batter, provided the baking powder is mixed first with the dry ingredients of the cake; that is, before the milk is added. Then in the process of baking, the gas expands forcing the cake batter to rise in the pan. In the finished cake you will see the tiny holes made by the expanding gas.

Put into a test tube one teaspoonful of baking powder. Here is another place where you must use your ingenuity. How can you pour baking powder from a spoon into a test tube without spilling the baking powder? Fold a piece of paper and put the teaspoonful of baking powder in the fold. Hold the paper between your thumb and fingers, with the lower edge of the crease over the mouth of the test tube. Wiggle your fingers back and forth. The contents flow into the test tube without spilling.

Now to prove that carbon dioxide gas makes a cake light, fill another test tube one-half full of water. Pour this into the first test tube. Immediately a chemical change occurs, producing CO_2 gas. Hold a lighted match over the mouth of the test tube. Remember CO_2 gas puts out fires. Does the match go out? If it does, it indicates that CO_2 gas has been formed. Now, do you understand why baking powder must be mixed with dry ingredients of a cake before adding the liquid? Otherwise, you might have a cake light in certain parts and soggy in others. To avoid such results the home chemist, your mother, is careful in following recipes, which are not too different from the experimental procedures of any research chemist.

TESTING ACID AND BASIC SUBSTANCES

Of course, you know what acids are. Some are so strong that they will eat away metals, shoes, and clothing. Others are weak or diluted and may play an important part in your daily life, as in the digestion of food in your stomach.

Bases are substances which neutralize acids. They are strong in their own way. Some bases have the power to dissolve grease or wool. Commercial products used to clear out clogged sink drains are composed principally of the base, sodium hydroxide, which dissolves sludge and grease. Other materials like soap contain mild bases. Here is a table of some acids and bases in the relative order of their strength:

Table VII. ACIDS AND BASES

ACIDS

Strong	Weak
hydrochloric acid	acetic acid (in vinegar)
sulfuric acid	hypochlorous acid (sold in jugs as chlorine water)
nitric acid	carbonic acid, the acid in ginger ale
phosphoric acid	tartaric acid (in baking powder)
	citric acid (in fruit juices)

BASES

Strong	Weak
potassium hydroxide	calcium hydroxide (milk of lime)
sodium hydroxide	magnesium hydroxide (used in milk of magnesia)
ammonium hydroxide (weak in household solution of ammonia)	

Then there are a large number of substances that are acid or basic when water is added to them. For example, blue vitriol or copper sulfate is acid when water is added to it. Washing soda or sodium carbonate becomes basic when water is added to it.

Now let us test some of the familiar substances around home. Take a lemon or a grapefruit. Cut it open. Draw a piece of blue litmus paper across the cut end. Blue litmus paper turns red in presence of an acid. Is it acid? What kind of acid is in lemon juice or grapefruit juice? Refer to Table VII.

Now open a bottle of ginger ale or sparkling water. Place a piece of moistened blue litmus paper across the top. What color does the litmus paper turn? What acid does the carbon dioxide gas in the ginger ale make when it comes in contact with water? Refer to Table VII.

Test the liquid in a bottle of chlorine water used in the home in bathrooms and kitchens. Use blue litmus. This shows an acid reaction.

There are a number of other substances in your home which you can test for acid reactions. How about vinegar? mayonnaise? French dressing for salads? There are a number of foods that have acid reaction to litmus. They are good for you. Would you refuse lemonade, orange juice, grapefruit juice?

Basic reactions require red litmus paper. The red litmus turns blue if a base is present. Moisten a piece of red litmus paper and touch it to a piece of soap. What color does the litmus turn? Remember that some substances with basic reactions have the power to dissolve or loosen grease and dirt. That is one reason why soap helps you to be clean.

Your mother may use ammonia in cleaning or in washing. Is ammonia water basic? Test it by placing a piece of moist red litmus paper across the top of an ammonia bottle. The ammonia gas which is given off by ammonia water dissolves again in the moisture on the red litmus paper forming the base, ammonium hydroxide.

$$\underset{\text{ammonia gas}}{NH_3} + \underset{\text{moisture on litmus paper}}{H_2O} \xrightarrow{\text{produces}} \underset{\text{ammonium hydroxide}}{NH_4OH}$$

Now you may test all soaps or soap powders in your home with red litmus. Do they have basic reactions?

Rub a little kitchen grease on a small piece of cloth. Moisten another piece of cloth with ammonia and rub the stain briskly. Remember, bases dissolve grease. Does the stain disappear? There are other chemicals that cause stains to disappear, but most of these are used by dry cleaning establishments.

NEUTRALIZING ACID AND BASIC SUBSTANCES

Fill your pyrex test tube half-full of water. Place in it a piece of laundry soap the size of a pea. Heat the test tube until the soap is dissolved. Or if you haven't an alcohol lamp or a Bunsen burner, shake the test tube vigorously. Pour half of the liquid into a beaker or glass tumbler. This liquid now contains the base present in soap.

Fill your other test tube half-full of vinegar. Vinegar contains mild acetic acid. Add the vinegar slowly to the soap solution. Test frequently with red and blue litmus. If acid is predominant, the blue litmus will turn red. If a base is predominant, the red litmus will turn blue. If you are very careful and painstaking, you can get complete neutralization where neither red nor blue litmus will be affected by the solution. This process, sometimes called titration, is one of the very important chemical procedures carried on by industrial chemists. But of course, industrial chemists have much better and more accurate apparatus than you have. Still, the procedure of titration has the same foundation.

SOLUTIONS

No one knows today the entire secret of solutions; why some substances dissolve and others do not. For example, common salt ($NaCl$) does not dissolve much more in hot water than in cold water. Many theories have been advanced concerning solutions. You will read about them later in your study of chemistry—including a polar theory involving electrical charges. Perhaps you will have the opportunity to add to scientific knowledge in this field. But first you must know how solutions are made and how they are affected by concentration and heat.

Fill your pyrex test tube one-quarter full of water. Be sure that it is not over one-quarter full. With the technique you have learned in pouring solids into test tubes, pour into the water about the same amount of Epsom salts, magnesium sulfate ($MgSO_4$) as you have water. You can get Epsom salts at any drugstore. Shake thoroughly. Does the solid dissolve? Add again the same amount. Shake the tube again. This time the Epsom salts do not dissolve.

A *dilute solution* is made when a small amount of a soluble substance is added to a certain quantity of water. A *concentrated solution* is made when a large amount of a soluble substance is added to a small quantity of water and the substance dissolves. A *saturated solution* is made when the water contains all it can dissolve of the soluble substance at a particular temperature.

Now you have found you have a saturated solution of Epsom salts. There are crystals present that cannot dissolve. How can you dissolve them? Of course, you can add more water. But if you did not add water, how would you dissolve the surplus crystals? Let us try heat. As you heat your test tube, and the temperature of the liquid rises, do the remaining crystals of Epsom salts dissolve? If they do, you have learned one important thing: increasing the temperature of a solution

197 *Students observing an experiment on the effect of pure oxygen. What evidence is there that violent burning is going on?* (*David Eisendrath*)

increases its ability to dissolve many soluble substances.

You can now understand why heat has to be used in making many solutions. *Solute* is the chemical name for what dissolves. A *solvent* is anything that can dissolve a solute. Now we are able to state these principles which govern solutions:

1. A solute is anything that dissolves.

2. A solvent is any liquid that dissolves a solute.

3. A dilute solution is one that has a little of the solute in the solvent.

4. A concentrated solution is one in which there is a large amount of the solute in the solvent.

5. A saturated solution is one that contains as much of the solute as it can hold at a particular temperature.

6. By increasing the temperature, more of the solute can be dissolved. With most solids, heat increases the ability of a liquid (a solvent) to dissolve a solute.

Solutions have great importance in chemistry and in the world's work. When you use another teaspoonful of sugar on your oatmeal or cornflakes at breakfast, you will remember that you are increasing the concentration of a solute (sugar) in your milk (a solvent).

INTERESTED NOW?

In this hobby chapter, there has not been room enough to open up many fields of chemistry to you. Only a few elementary experiments have been presented. You have not been instructed to make dyes, or soaps, or plastics. With further instruction from chemistry manuals, you can go ahead in these fields.

But there is one word of caution.

You should use the scientific method presented in this book in doing experiments (Chap. 3). Always have a piece of paper handy and a pencil. Write down your results. Form your own conclusions and write them down. Be sure that before you start an experiment, you know the procedure to follow. And be careful. Do not be like some people who like to mix everything together in the chemistry sets they receive as gifts—and get nowhere.

In the reading list at the end of this section, you will find a number of good books on chemistry. Start with the simple ones and go on to the more difficult ones as you learn chemistry. and become more competent in your use of the tools of chemistry. You will find a note with each reference describing the nature of the book.

After you have done some work in chemistry, you may decide to become a chemist. Further training in high school and college will test whether your decision is a good one. But whether it is or not, you will have had fun and will have learned something about one of the important sciences in the world.

Reading for the Amateur Chemist

1. *Simple Chemical Experiments* by Alfred Morgan, Appleton-Century, 1941. Elementary experiments for boys and girls who would like to know more about chemistry of the home.

2. *Invitation to Experiment* by Ira A. Freedman, Dutton, 1945. Challenging interest, this book has helpful suggestions on ways and means to provide apparatus, to use chemicals, and to experiment.

3. *Mystery Experiments and Problems* by Frank and Barlow, J. O. Frank, Oshkosh, Wisconsin, 1937. A well-known book of spectacular experiments that create interest. Good for science clubs or the home.

4. *Lecture Demonstrations in General Chemistry* by Paul Arthur, McGraw-Hill, 1939. More advanced experimental work is emphasized. It is fine for the advanced beginner.

5. *The Magic Wand of Science* by Eugene Nelson, Dutton, 1938. Explanations concerning how far experimentation and discovery have gone along the paths of the broader aspects of science.

6. *Science Calls to Youth* by Raymond F. Yates, Appleton-Century, 1941. A real inspiration and guide to young people who wish to explore the scientific world through experimentation.

7. *Science for the World of Tomorrow* by Gerald Wendt, Norton, 1939. An analysis of achievements of the past and present and their influence on the future.

8. *How Things Work* by George Harrison, William Morrow Co., 1941. A book that shows how experimentation has proved its worth in the world of today.

9. *Everyday with Chemistry* by Bunzell and Niseison, Grosset and Dunlap, 1937. Chemical experiments dealing with all phases of industry. Valuable for individual work and interestingly organized.

UNIT FIVE

IMPROVING BIOLOGIC PRODUCTION

In the laboratory, man can put his fields and orchards into test tubes. He is always experimenting to find out how to get the most from the soil and its minerals, water, light, air, and plants. (Shell Oil Company)

Is America vanishing?

People who lived in Oklahoma during the week of May 11, 1934 said they had never seen anything like it. And they hoped they never would again.

Great winds carrying gritty, rasping soil roared over the Great Plains area. These winds filled houses and barns with dirt and grit. Worse than that they picked up the rich topsoil and carried it in a huge cloud which settled on ships almost 200 miles out in the Atlantic. Aviators could not climb above the dust cloud. The Chief of the Soil Conservation Service thought that over 300,000,000 tons of topsoil went up into the air to be lost forever.

Dust storms are dramatic. Everybody notices them. But few people notice small muddy streams, the little rivulets which become brown with soil. These little waters are carrying the soil of North America into the sea.

You ought to know the enemy which does this damage. It is called soil *erosion* (ē rō′zhŭn), the removal of soil by water or wind. The sign of erosion by wind is the dust storm. The sign of erosion by water is the gully.

Erosion has made 57,000,000 acres or 3 per cent of the total lands of the United States practically worthless to the present generation. Another 12 per cent of our total lands needs immediate attention or it too will become worthless.

This is not all. Hand in hand with the destruction of our soil has gone the destruction of our forests. Without the fallen leaves and roots to hold the rain and snow water, floods have poured down hillsides into the rivers causing destruction to cities and farms alike. Without the forest to give them food and shelter, wild animals have been unable to survive. Fisherman have "fished out" many streams and lakes. What a waste of our national wealth! Where land, forests, or streams have been destroyed, poverty starts to march. For poor land cannot support people.

About 50 years ago a few scientists and public-spirited citizens like the great conservationist, Gifford Pinchot, former governor of Pennsylvania, saw the danger ahead. Today, our state and national governments are awake to the danger and are spending millions of dollars on conservation of our biological resources—our soil, our plants, our animals. The success of the state and national programs of conservation depends on the co-operation of every person in the United States. What part will you play in this important program?

To play an active part in helping solve conservation problems, you will need to understand how living things carry on biologic production. In biologic production, plants and animals (living things) produce many of the materials which we use for food, clothing, medicine, and shelter.

The steps toward understanding biologic production are indicated by these questions:

Why are green plants the basic food factories of the world?

Why do we need to save soil and its minerals, our most important natural resources?

How can we increase reproduction of our wild and domestic plants and animals so that we shall have more food, lumber, medicine, and other necessities of life?

How can young people co-operate with the men who produce our most important materials for life and living—the men and women who work the farms of the nation?

You are one of those who will supply the answers to these questions upon which the future of our nation depends.

CHAPTER 16

FOOD FACTORIES OF THE WORLD

What was the scientist Van Helmont up to? First, he had taken a tub of soil and weighed it carefully. Then he had planted in it a young willow tree weighing about two pounds. In Holland in the year 1605, this was strange behavior indeed!

The willow tree grew fast. It was watered regularly. Some time later after the willow had become quite large, Van Helmont carefully removed the willow from the tub. Then he weighed the tub with its soil separately from the willow tree (Fig. 198).

When he placed the tub with its soil on his big scales, it weighed about one pound less than when he had first put the willow in it. When he weighed the willow, he found it had gained 70 pounds. Van Helmont decided that the increase in weight of the willow could not be due to the soil.

He concluded, therefore, that water was responsible for the growth of the willow. At that time scientists knew little about the composition of water, air, and soil, and the way plants grow. Van Helmont's conclusions were partially wrong because he did not have the facts we have today. The experiments in this chapter will give you some of these facts.

INVESTIGATING THE WORLD'S FOOD FACTORIES

In the past century, a great many facts have been gathered about plants and the materials they need for growth. These facts lead us to make this statement: *We are all dependent on green plants for our very lives.*

SEALING UP A LIVING THING

In an Eastern high school a group of students repeated Van Helmont's experiment. Instead of a willow they used a common water plant like *Elodea* (ē lō′dē *ȧ*). They found that a sprig of their green water plant weighed 1.1 grams.[1] They placed the sprig in a large test tube filled half with aquarium water and half with air. Then they sealed the tube by pulling it out in a hot flame and sealing the glass. They

[1] 28.4 grams = 1 ounce
16 ounces = 1 pound
454 grams = 1 pound

found the weight of the sealed tube to be 57.5 grams.

Then they placed the tube in indirect sunlight for three weeks. By then, they reported, the sprig had grown longer, though the sealed tube still weighed the same (57.5 gms.). As a matter of fact, when they removed the sprig, they found it to weigh 1.7 grams (a gain of .6 of a gram). What did the plant use for growth—water, air, or minerals? Since we know that the plant was sealed in the test tube, it must have obtained its food and materials for growth from the substances in the tube.

An analysis of the contents of the tube showed mainly these substances:

1. Water with its dissolved minerals, and the dissolved gases oxygen and carbon dioxide.

2. Air, composed of oxygen, nitrogen, and carbon dioxide (and a trace of rare gases).

Which of these does the plant use for its growth? Perhaps we can devise an experiment to anwer this question.

GREEN PLANTS AND CARBON DIOXIDE

Here is a hint: If we could determine which of the foregoing substances is used by the plant, it would be easier to determine which it uses for growth. For one substance, carbon dioxide, we have a ready method of detection. There is a certain blue dye called bromthymol blue which is just right for the experiment. First, water plants and animals can live in it. Second, when carbon dioxide is added, it turns yellow. When the carbon dioxide is removed, the dye turns back to blue. Chemists call such substances indicators. Thus this indicator tells us whether carbon dioxide is present or absent.

Now let us take 20 tubes and put sprigs of green water plants, water, and some blue indicator in 15 of them. In five more tubes (the controls), we shall have water and the blue indicator but no plants. In order to make certain

198 *A diagram illustrating Van Helmont's experiment. How did Van Helmont explain the willow's gain in weight?*

that we have enough carbon dioxide to test we bubble carbon dioxide into each of the 20 tubes. In a few seconds, each one turns yellow, indicating the presence of carbon dioxide.

Now let us put all the tubes in the sunlight. In one hour or less, all the 15 tubes with plants in them have turned blue. This shows that carbon dioxide has disappeared. Where? A glance at the five tubes without the plants tells us at once. For these are still yellow, showing that the carbon dioxide has not been absorbed. The only difference between the set of 15 tubes and the set of five control tubes is the absence of the plants in the controls. It must be that the green plants have absorbed the carbon dioxide. This can be shown to be true of all green plants.

We may, therefore, come to our first conclusion: *Green plants can absorb carbon dioxide.*

GREEN PLANTS AND LIGHT

But notice we suggested that the tubes containing the plants be put in sunlight. What would happen if we put them in the dark? Let us repeat the experiment. We shall take 20 tubes with green plants and add bromthymol blue. We shall then bubble CO_2 into each tube, thus turning the dye yellow. This time, however, we shall put all the tubes in the dark. After one hour in the dark all the tubes are still yellow, showing the presence of carbon dioxide. Even after 24 hours they are still yellow—not blue as they should have been had the carbon dioxide been absorbed. This fact is true of other plants. When we put these tubes in sunlight, the dye turns blue. The plants have absorbed the carbon dioxide. The conclusion is plain: *Green plants absorb carbon dioxide only in the light.*

ABSORBING CARBON DIOXIDE

How does the carbon dioxide get into a plant such as a geranium or apple tree? Let us use our microscopes. We take an apple leaf and with a forceps peel off the lower, transparent, skinlike tissue, the lower epidermis (ĕp′ĭ dûr′mĭs). We put it in a drop of water on a slide and examine it. There we see many tiny openings in the leaf, called *stomates* (stō′māts, Fig. 199).

These openings can be made larger or smaller by the two sausage-shaped guard cells on each side. There is ample evidence to show that carbon dioxide enters through these openings. It has been found that if these stomates are closed by vaseline, no CO_2 enters into the plant.

TRANSFORMING CARBON DIOXIDE

What does the plant do with the carbon dioxide it absorbs in sunlight? The solution lies in the answer to this next question: What does the plant do in the sunlight that it cannot do in the dark?

Is it that plants make food substances only in sunlight? It is known that a plant stores one food it makes in the form of starch. By a simple test we can tell whether starch is present in any part of a plant. First, let us take a geranium leaf and cover half of it with black paper while the other half is exposed to sunlight. After 48 hours, we test both halves for the presence of starch. In order to do this, we must first get rid of the green coloring matter in the leaf by boiling the leaf in alcohol. (Alcohol should not be boiled over an open flame. It catches fire. An electric hot plate or a water bath is best.) Then we stain the leaf in iodine because iodine is an indicator of the presence of starch. The evidence is clear. The half leaf exposed to sunlight stains

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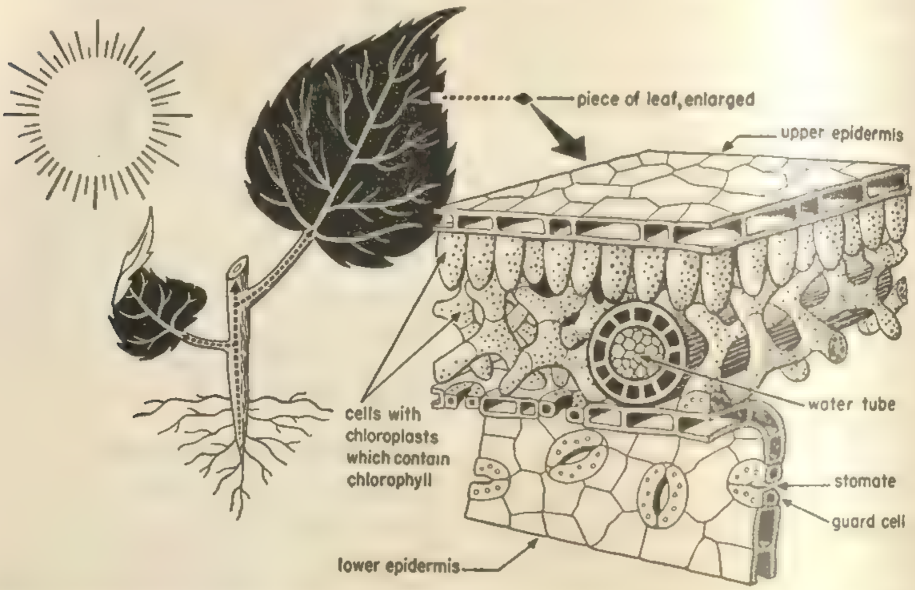
blue; it contains starch (Fig. 200). The half leaf covered by black paper is free from starch. This is repeated many times but the same results are obtained. The conclusion is plain: *Green plants make starch only in sunlight.* Actually, it has been found that starch is not made at first but that a kind of sugar, called glucose (glōō'kōs), is. Most of this glucose is changed into starch.



199 *A diagram of a cross section of a green leaf. How do gases enter the plant?*

HOW DO GREEN PLANTS MAKE STARCH?

We know from our previous experiment that green plants can absorb carbon dioxide only in light, not in the dark. Since they make sugar only in light and absorb carbon dioxide only in light, may we say that plants use carbon dioxide to make sugar?

The chemist's formula for glucose sugar is $C_6H_{12}O_6$. Notice from the formula that a chemist finds hydrogen and oxygen as well as carbon in sugar when it is analyzed.

But CO_2 has only carbon and oxygen in it. Where does the plant get the hydrogen? A ready source appears to be water (H_2O) which you remember has hydrogen and oxygen. And we know that the plant takes in large amounts of water.

As a result of much experimentation, scientists have found that *in light a green plant makes glucose sugar from water and carbon dioxide.*

RELEASING OXYGEN

If we seal a snail in a tube filled with water plants, we find that the snail lives and grows. We can see that it gets its food from the water plants. The carbon dioxide given off by the snail in breathing is absorbed by the plant. But where does the snail get the oxygen it needs in order to live?

By careful experiments, scientists have shown that in sunlight green plants give off oxygen. The plant Elodea

can be seen to give off small bubbles of gas in a rapid stream. When this gas is collected it is shown to contain a good deal of oxygen. It is clear that *in sunlight green plants give off oxygen.*

In land plants, this oxygen leaves the plant through the stomates of the leaf (Fig. 199). We use this oxygen for our own respiration.

PHOTOSYNTHESIS—A BASIC PROCESS

Whenever you have a good many facts which seem to be related, it is a good idea to see if you can put them together in a definition or an equation. We have, in the last few pages, gathered some facts about what green plants do in sunlight. We know from our series of experiments and by reasoning that:

Green plants *absorb carbon dioxide only in light.*

Green plants *manufacture sugar only in light.*

Green plants *use water in manufacturing sugar.*

Green plants *give off oxygen in light.*

Now it seems clear from these facts that *green plants use carbon dioxide and water to make sugar.* Oxygen is released during the process of food-making. Or we may write it this way:

$$\underset{\text{carbon dioxide}}{6CO_2} + \underset{\text{water}}{6H_2O} \longrightarrow \underset{\text{sugar}}{C_6H_{12}O_6} + \underset{\text{oxygen}}{6O_2}$$

As you remember, most of the sugar is eventually changed into starch.

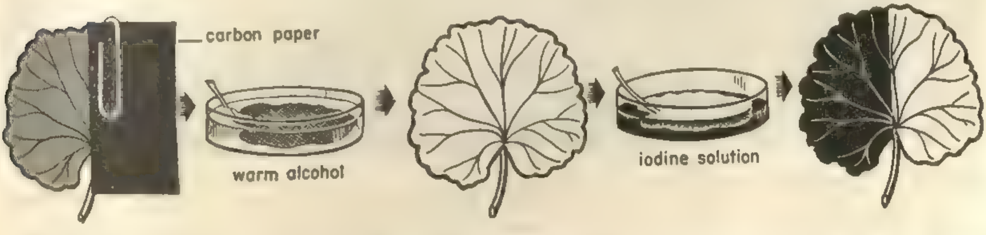
This equation represents a basic chemical reaction in this world. You could not live if it did not go on. Scientists call this reaction *photosynthesis* (fō′tō sĭn′thē sĭs). *Photo* refers to the light which is needed. *Synthesis* means a putting together. Photosynthesis is a putting together of CO_2 and H_2O in the presence of light. As a result, starch and oxygen are produced. These substances are used by all living things.

ENERGY FOR PHOTOSYNTHESIS

In this world of ours we cannot get something for nothing, that is, without using energy. In photosynthesis, we get starch which has stored-up chemical energy from carbon dioxide and water. What is the source of the energy for photosynthesis?

You noticed that photosynthesis could not take place in the dark (p. 297). From this, you may assume that the energy for this reaction comes from the sun. We are, in other words, dependent upon the sun. We are dependent upon it for the energy for the fundamental process in the world—food-making or photosynthesis.

You must not think that we know all there is to know about photosynthesis. We know only the barest essentials.



200 *An experiment illustrating the effect of the absence of light on starchmaking. Iodine stains starch blue-black* (leaf at right). *Do plants make starch in the absence of light?*

We hope that investigations with radioactive substances like the following will yield more facts about this process.

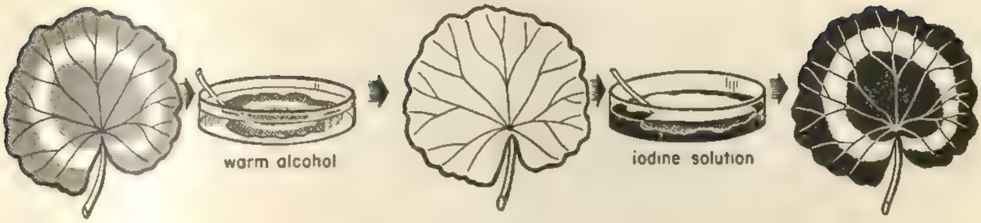
RADIOACTIVE SUBSTANCES AND FOOD PRODUCTION

As soon as radioactive substances began to be produced in the atomic piles, scientists began to use them as tools of experimentation to discover what actually happens in photosynthesis. For instance, what happens to the CO_2 when it enters the plant? We know that it is used in the production of sugar and starch (p. 298), but how does this actually take place?

Scientists secured radioactive carbon from the Oak Ridge plant of the Atomic Energy Commission. This carbon gives off rays that can be detected by instruments like the Geiger counter or by photographic plates. They combined the radioactive carbon with oxygen to make the gas CO_2. This gas they placed in a chamber with growing plants. The CO_2 entered the stomates of the plant leaves, and the radioactive carbon entered the starch which the plant manufactured. By using Geiger counters, the scientists were able to follow the path of the carbon in its journey through the plant.

Scientists were thus able to trace the CO_2 used in photosynthesis. The experimenters discovered an important fact. CO_2 is not immediately built into sugar by the help of chlorophyll. The CO_2 is first built into another substance

201 *An experiment at the Brookhaven Laboratory, Long Island, New York. Radioactive substances are placed in a pole at what appears to be the bull's-eye in this targetlike pattern. Crops are planted in circles around the pole. The results of these experiments, when they are known, will help us to understand further the effects of radiation on growing things.* (*U.S. Atomic Energy Commission*)



202 *An experiment on a silver geranium leaf, showing how the absence of chlorophyll affects the making of starch. A silver geranium leaf is green with a white pattern in it* (leaf at left). *Chlorophyll is taken out by boiling in alcohol* (middle leaf). *Iodine stains starch blue-black* (leaf at right). *How does the absence of chlorophyll affect photosynthesis?*

whose nature is not yet known. This intermediate substance then helps in the formation of sugar. With further investigation by means of radioactive carbon this unknown substance may soon be identified. Then, we will be one step nearer to understanding exactly what happens in the complex process of photosynthesis.

RADIOACTIVE SUBSTANCES AND PLANT USE OF MINERALS

Scientists are using the new radioactive substances produced at Oak Ridge to study another interesting plant problem: What happens to the minerals absorbed by the roots? Substances containing radioactive phosphorus are placed in the soil. As they are absorbed by the plant, the scientist investigating the problem can follow the phosphorus as it goes up into the plant by means of a Geiger counter. By methods similar to this one, it has been discovered that in corn plants phosphorus is concentrated in the corn grain; that elements like zinc are concentrated in the nodes, those parts of the corn plant where the leaves join the stalk. Other experiments reported from the universities of Pittsburgh, Purdue, Wisconsin, Minnesota, Hawaii, Texas, and California, as well as many others, indicate that work of this sort is going on in many research centers. It will not be long before we know many important facts about photosynthesis and plant growth which may enable us to produce more and better food (Fig. 201).

ONE OF THE MOST IMPORTANT SUBSTANCES IN THE WORLD

You have just considered one of the most important chemical reactions in the world—photosynthesis. Now you will investigate one of the most important substances in the world.

Bubble CO_2 into H_2O in a test tube in the bright sunlight. Then test for starch. Starch is not manufactured. Probably there is something in leaves responsible for photosynthesis. Let us take a leaf which has a white and green pattern; the silver leaf geranium will do. Will we find starch in both the green and white portions? After a few hours in sunlight, we test for starch. We find that only the green part has starch (Fig. 202). The white portion has none! This experiment may be repeated many times on different plants.

Scientists have discovered that in the green part of the plant there is a substance which enables green plants to

make starch. This substance is called *chlorophyll* (klō′rō̆ fĭl). It is present in tiny bodies called chloroplasts (klō′rō-plăsts), which are found in the cells of the green plant. Without chlorophyll, plants cannot manufacture starch. You can see why chlorophyll may be called one of the most important substances in the world. Without the results of photosynthesis—starch and oxygen—we could not live. Scientists have also discovered that green plants use starch to make other food substances. In short, chlorophyll is a basic substance used in food production by the green plant.

Colorless plants, such as the mushrooms and molds, have no chlorophyll. Colorless plants are called *fungi* (fŭn′-jī). Fungi cannot manufacture their own food. They must, therefore, get their food from dead or living things. A mushroom, for instance, gets its food from dead or living leaves or wood. A *fungus* (fŭng′gŭs) like bread mold gets its food from bread or moist grain. On the other hand, the fungi which destroy our crops, like the smuts and rusts, get food from the living corn or wheat plant.

TESTING A STATEMENT

The title of this chapter is "Food Factories of the World." Following our habit of testing all statements to see whether or not they are true, you might say: There are animals like the tiger and lion which eat meat only. They feed only on animals such as zebras, wild cattle, or deer. Well, what do zebras, wild cattle, and deer eat? They

203 *This balanced aquarium in the Bronx Zoo in New York City illustrates the carbon dioxide-oxygen cycle. If there were no fish, would the plants survive?* (*New York Zoological Society*)

feed on grasses and other plants, and turn these green plants into more zebras or deer.

Animals also produce milk, beefsteak, and eggs from the green plants they have eaten. Clearly then: *The green plant is the basic food factory of the world.*

THE CARBON DIOXIDE–OXYGEN CYCLE

From what you have just learned, you can predict that a small fish placed in an aquarium stocked with green plants will survive, for it will get oxygen (and food) from the plants. In turn, the carbon dioxide given off by the small fish will be absorbed by green plants as they carry on photosynthesis.

An aquarium that is sealed from the outside air is a small world in itself. Can you see that the principles which govern this sealed aquarium govern this entire earth as well? Like millions of other living things, you are giving off carbon dioxide, which will go into the air. Later (during daylight) some green plant somewhere on this earth may absorb it. Right now you are taking in oxygen. This oxygen may have been produced by green plants. There is thus a dependence of green plants and animals upon each other. This idea is illustrated for you in Fig. 203.

You can see that animals absorb the oxygen plants give off during photosynthesis. On the other hand, the plants absorb the carbon dioxide animals breathe out. Plants then use carbon dioxide as a raw material in manufacturing food. However, all plants use oxygen just as human beings do, just as all animals do. Indeed, scientists have proved that green plants take in carbon dioxide and oxygen at the same time. But they use oxygen in oxidation and carbon dioxide in food-making.

204 *A plant suffering from lack of certain minerals. (Bureau of Plant Industry, Soils and Agricultural Engineering)*

RAW MATERIALS FOR THE FOOD FACTORIES

Any gardener knows that the size of his vegetables, the number of tomatoes, or peas, or the size of his ears of corn all depend partly upon whether or not his soil is good.

PLANTS HAVE MANY NEEDS

Perhaps you now have the idea that plants need only light, chlorophyll, carbon dioxide, and water—and we have photosynthesis. Not at all. To make up chlorophyll itself, plants need iron and magnesium. A plant also needs substances to build up its own roots, stems, and leaves. It needs, among many other substances, phosphorus, nitrogen, potassium, iron, and magnesium—just as you do. You get these from the food you eat. A plant must get them from the soil in which it grows (Fig. 204).

205 *Irrigation projects, such as the one shown here, supply the water necessary for the growth of plants.*

A plant cannot get these minerals—iron, magnesium, potassium, nitrogen, or phosphorus from dry soil. These minerals must be dissolved in water before the plant body can use them. Here is another reason why water is so important to plant growth.

Have you ever seen a desert? There are minerals in the sandy soil, but there is no water. The minerals are not dissolved. Thus there is very little plant growth. After the seasonal rains, a desert may suddenly come to life. Green plants seem to spring up, grow in a few weeks, bloom, and produce seeds. Then the plants die as the water evaporates in the hot sun. However, their seeds grow into new plants next season.

Some of the desert land in our west and in other desert areas has been reclaimed by *irrigation.* Irrigating land means bringing water to it by means of ditches and pipes (Fig. 205). The minerals in the soil dissolve in this water and enter the plants. Irrigated deserts are soon rich in vegetation.

How much water does a plant need? The amount differs with the season and with the plants. In winter, after the leaves fall, most plants are inactive or dormant. Dormant plants take in very little water; they do not make starch. However, the roots of evergreens such as the pines and mountain laurels, which keep their leaves, take in small amounts of water on warm days.

It is during the growing season, spring and summer, that plants use tremendous amounts of water. For instance, a big beech tree, 100 years old, withdraws from the soil about 65 barrels of water during a season. And an acre of corn may use during its growing season as much water as would amount to five or six inches of rain on the acre. One corn plant may use five to ten times its own weight of water a day. Leafy plants like alfalfa may use 175,000 times as much water as do certain leafless desert shrubs.

Plants, like all living things, cannot live without water and the minerals they dissolve. Without soil minerals, which support the plants we eat, no animal can grow. Without soil minerals, nations cannot develop. Truly the basic wealth of a nation is good soil.

CARRYING THE MINERALS

How does the water, carrying the minerals, get to every part of the plant? In a plant with a transparent stem like jewelweed, we can see long lines running up from the roots to the leaves. These lines are really tubes or ducts; they come in groups called fibrovascular (fī′brô văs′kû lēr) bundles.

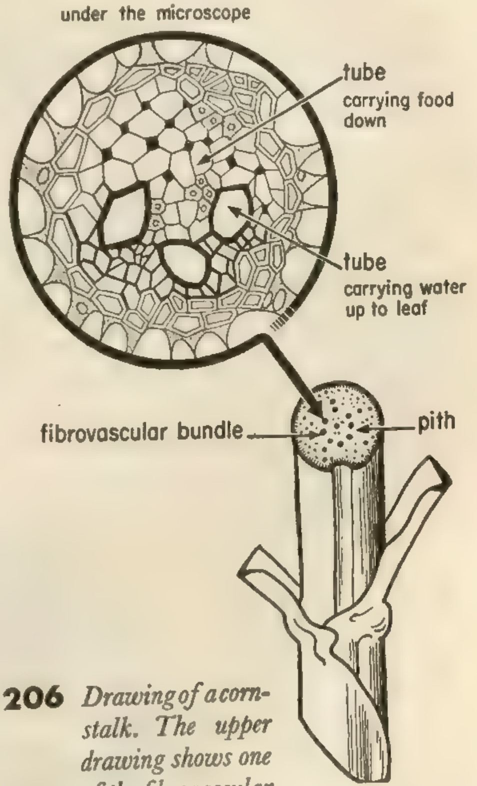
Under the microscope, the ducts in a plant like corn can be easily seen (Fig. 206, top). In corn, you may even see the bundles with your naked eye (Fig. 206, bottom).

Scientists have discovered that some of these ducts carry the water with its minerals up to the leaves. Others carry the food manufactured in the leaves down to all parts of the plants.

ABSORBING MINERALS

Once the mineral-carrying water is in the ducts, it is carried up into the leaves. How does it get into the ducts in the first place? If you have ever helped transplant a tree, you have an idea. Even a small-sized tree needs a good deal of digging to get out most of its roots unharmed. Of course, one of the jobs of a plant's roots is to anchor it firmly in the soil. However, this doesn't explain why a tree dies within an hour without its roots.

Let us find out. In the laboratory, take some radish seeds and place them between two moist pieces of blotting paper. In about three days, examine the seeds. Notice the white roots each one has sent out. Even with your naked eye you cannot fail to see a fuzz on the



206 *Drawing of a cornstalk. The upper drawing shows one of the fibrovascular bundles and its tubes as they look under the microscope. (Adapted from drawing by Marion A. Cox for "Exploring Biology: Third Edition," by Ella Thea Smith, courtesy Harcourt, Brace and Company)*

the root. This fuzz is made up of many small hairlike structures sticking out from the root. These are the *root hairs* (Fig. 207).

Examine some root hairs under the microscope. Notice that each one is a long thin hairlike cell. Each plant has millions of these root hairs.

Perhaps the water with its minerals goes into the plant through the microscopic root hairs. Why don't the minerals stay outside of the root hair? Let us see.

SOME EXPERIMENTS WITH SOLUBLE SUBSTANCES

You can do this group of experiments at home. Take a glass of water and let a drop or so of red or blue ink from your pen fall into it. When it colors the entire glass, the ink has spread throughout the water.

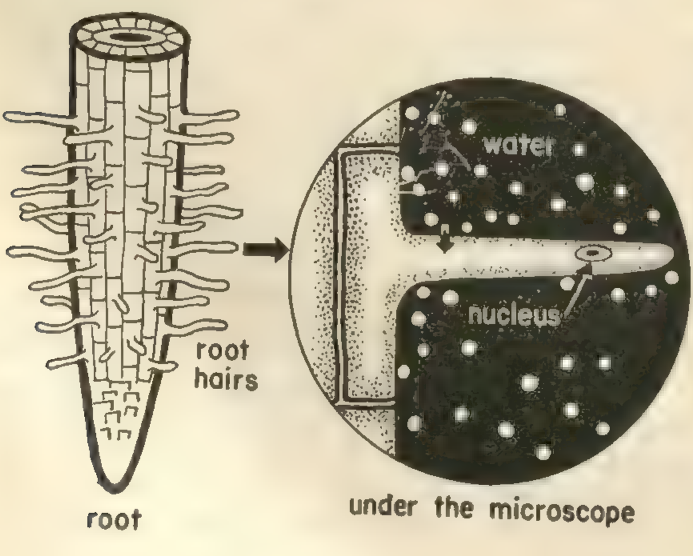
Then add a pinch of table salt to another glass of water. Watch it disappear in the water as it dissolves. After it disappears you will be able to taste the salt in the water. The salt has spread throughout the water.

Scientists explain the swift spreading of substances in water in this way. You know that salt is made up of molecules. As you remember, these molecules are always moving about, some slowly, some rapidly. As these molecules move about they go farther out into the water and mingle with the water molecules. Finally, all the salt molecules mingle with those of the water. The dissolved substance, in this case salt, has spread out evenly in the dissolving fluid—water. This is called *diffusion*. And now let us find out why diffusion is the method by which soil minerals enter root hairs.

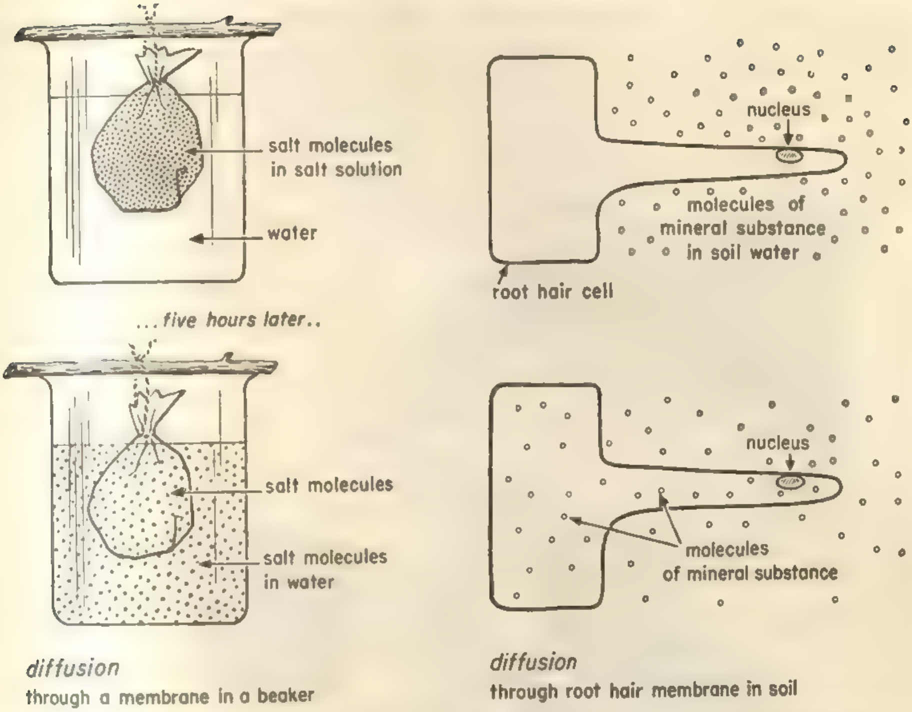
DIFFUSION THROUGH MEMBRANES

Since each root hair is a cell, it has a *membrane* around it. Do substances diffuse through membranes?

Take a piece of cellophane (which will be our membrane) and shape it into a bag. Put some salt solution into it. Tie the bag with a string and suspend it in a glass of water. After a few hours taste the water in the glass. It is salty. The salt must have diffused through the cellophane membrane into the water in the glass. On the other



207
Root hairs. Each root hair is a cell through which soil minerals enter the roots of plants.



208 *Diffusion. Compare the diffusion of salt in the jar with the diffusion of mineral salts into the root hair.*

hand, insoluble substances like glass, sand, or starch do not diffuse through membranes.

It is known that soluble salts found in the soil also diffuse through the living cell membranes of the root hairs. From the roots the minerals and water travel up to the ducts and throughout the plant (Fig. 208).

THE ASSEMBLY LINE IN A GREEN PLANT

You have probably seen an assembly line in a manufacturing plant, or a movie of one. The parts, let us say, to manufacture an automobile come in at one end, the finished product goes out at the other. Each part of the factory has a definite job to do. So it is with our green plant (Fig. 209). Here is its assembly line:

1. Water and minerals are absorbed by root hairs.

2. The water and the minerals dissolved in it travel up the ducts to the leaves.

3. In the leaves, carbon dioxide enters through the stomates.

4. In the leaves, chlorophyll combines the carbon dioxide and water to make sugar. The energy for this reaction comes from the sunlight.

5. The ducts carry the manufactured sugar to all parts of the plant. Some of the sugar is stored and some of it is used for growth.

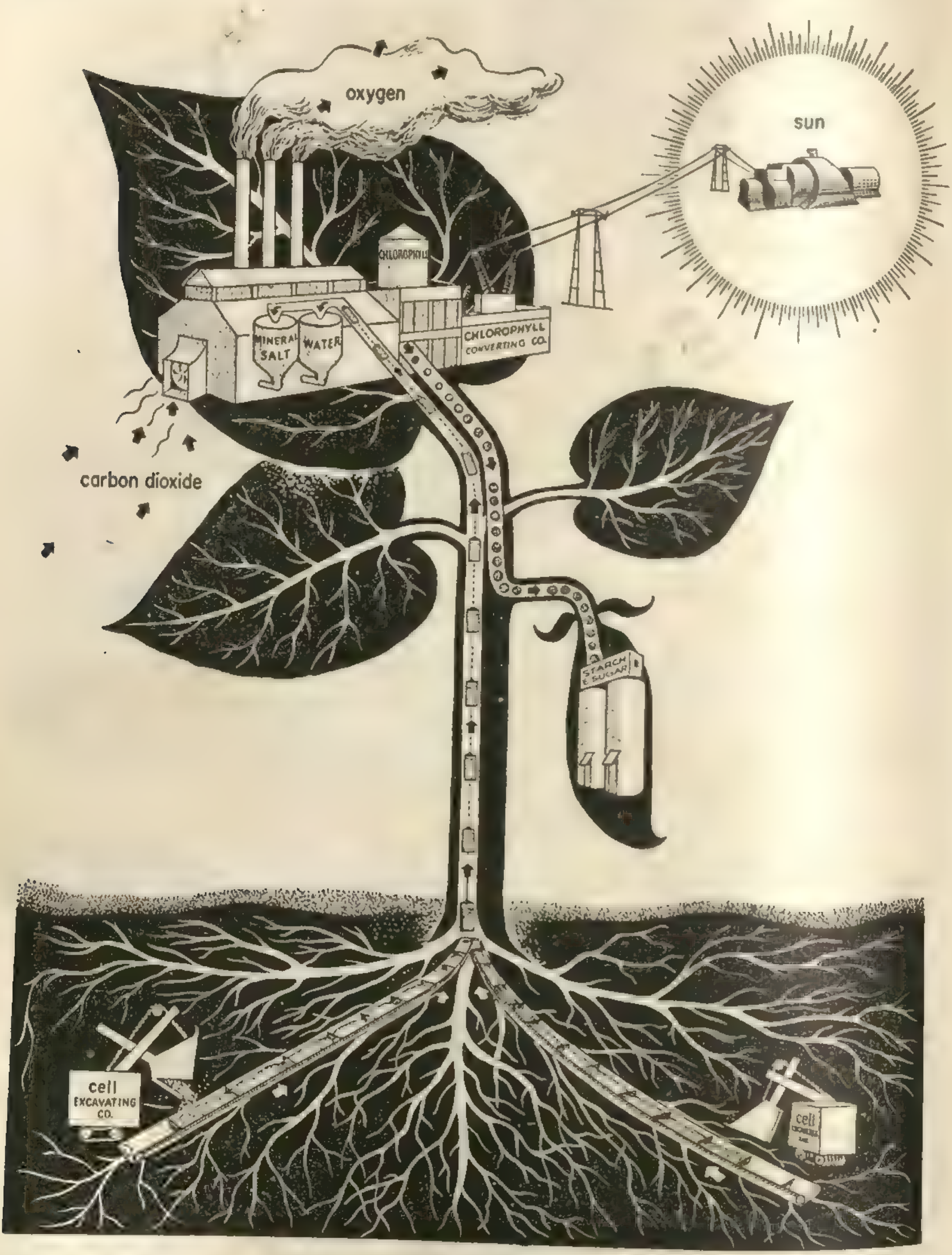
6. Oxygen and water are given off from the leaves through the stomates.

This is the way the green plant makes sugar, a basic food substance.

STORING FOOD

Some of the starch or sugar a plant makes is stored or made into other foods. Seeds contain starch, oil, or

sugar. Starch may be stored in underground stems like the white potato. Starch or sugar may also be stored in roots like those of the carrot, beet, radish, or sweet potato. And, of course, sugar is found in most fruits.



209 *A diagram showing the plant as a starch factory. What are the raw materials needed by the factory? What is the source of energy? What is one waste product?*

Oil is stored food which is found in most nuts, like the walnut, and in some seeds like those of cotton and flax.

Later on you will learn of the great importance of vitamins to your health. Plants are the basic producers of vitamins. You also know that plants are storage places of important minerals necessary to your health.

SUPPLYING FOOD TO THE WORLD

The production and the storage of food needed by mankind do not just happen. They require hard work by the farmers of the nation. On the farm, the most important business in the world goes on—that of growing food. The farmer is the expert in this all-important job.

A farmer needs to do these things. He needs to start his plants and animals growing and reproducing. Plants must produce more plants, and animals must produce more animals; that is, they must *reproduce*. The farmer can feed you and the world because he knows how to get his animals and plants to reproduce. He cannot do this unless his soil supplies his plants with the water and minerals needed for photosynthesis. Therefore, his first big job is to look to his soil. His farm can be only as rich as his soil. His crops will be as good as his soil. Poor soil means less photosynthesis.

As a matter of fact, there is a clear line from poor soil to poor farms to poor people.

GOING FURTHER

1 *Examining stomates.* Take the leaves of the plants you find around your school. Use a microscope to make your examination. Are there stomates only on the undersurface or the top surface, or both? Keep notes of your observations.

2 *Investigating absorption of CO_2.* Vaseline will close the stomates. Take a plant like a geranium and smear the underside of one-half a leaf, three-quarters of another leaf, and then an entire leaf with vaseline. Do the same for the upper surface of other leaves. Expose the plant to the sunlight. Test the leaves for starch (Fig. 202).

3 *Experiment on photosynthesis.* Take two bell jars, each with openings at the top. Put a geranium under each jar. Put a jar of limewater which absorbs CO_2 under one. Now seal the bell jars.

Place both in a dark place for 24 hours to rid the leaves of starch. Now place both jars in the light. After a day in the light, test each one for starch. What is the effect of lack of CO_2?

4 *Diffusion.* By using certain chemical reactions you may be able to "see" how diffusion takes place. Fill a test tube with water and add a few drops of 1 per cent phenolphthalein (fē′nōl thăl′ēn) in alcohol. (To make this solution, dissolve one gram of phenolphthalein in 100 cc. of water.) Now with a rubber band fasten a goldbeater's membrane or a piece of cellophane around the mouth of the tube. Invert this over a bottle of ammonia. Molecules of ammonia diffuse through the membrane and react with phenolphthalein to color it red. Watch the spread of the red color as the diffusion of ammonia molecules takes place.

5 *Words are ideas.* Can you use these words in a sentence which will give their meaning? Use the glossary.

photosynthesis	mineral
chlorophyll	ducts
stomate	carbon dioxide
diffusion	oxygen
root hair	nitrogen
fungus	starch
membrane	glucose

6 *Put on your thinking cap.* A boy did the following experiment. He grew tomato plants in soil which had all the substances commonly found in soil, except magnesium. The leaves of his plants were speckled with white, some turned yellow, others fell off. From this the boy could conclude:

1. that magnesium is needed to form chlorophyll

2. nothing—because a control experiment was lacking.

3. that magnesium is necessary to proper growth

4. that speckling or yellowing is a result of a lack of magnesium.

Select the conclusion you think is the correct one and give the reason for your selection. If you think you can improve on this experiment, plan a better one and show it to your teacher.

7 *Test yourself.* In your notebook, match the number in front of each item in the left column with the letter of the item to which it is most related in the right column. Do not mark this book.

1. the green coloring matter of plants	A. bromthymol blue
2. a gas given off by plants during photosynthesis	B. calcium
3. an indicator to determine presence of CO_2	C. carbon dioxide
4. a form in which food is stored in plants	D. chlorophyll
5. an opening in a leaf through which water and gases pass	E. hydrogen
6. a gas required in photosynthesis	F. iron
7. an important mineral needed to build chlorophyll	G. nitrogen
8. the most abundant gas in the air	H. oxygen
9. a source of plant energy	I. in solution
10. a form in which minerals are taken into plant	J. starch
	K. stomate
	L. sun
	M. water

CHAPTER 17

PRODUCTION THROUGH REPRODUCTION

Lazaro Spallanzani, a great Italian scientist of the eighteenth century, asked a simple question which led to an ingenious experiment. Could it be possible, he asked himself, that microscopic living things could come from dead material? Many other scientists of the eighteenth century claimed that they could.

He took a microscope slide and placed on it a drop of water containing a small protozoan, a microscopic single-celled animal. Next to it he placed a drop of water from a flask which had been boiled long enough to kill all living things. Under his microscope he carefully joined the two drops by drawing a bridge of water from one drop to the other. Now he watched a single animal, only one, swim across this bridge of water into the drop of pure water. When this animal had reached the drop of pure water, Spal-

lanzani destroyed the bridge of water by wiping it away with a clean brush. Now he had one microscopic animal imprisoned in a drop of water.

As he watched, he saw before him evidence that the scientists who believed that microscopic living things came from dead material were wrong. For he saw what would be seen many times; the microscopic animal divided into two. It had reproduced its own kind. And since Spallanzani's experiment, scientists have piled up a great deal of evidence to show that living things reproduce their own kind. They never come from dead material.

REPRODUCTION AND THE FARMER

What has reproduction of microscopic living things to do with better production on farms? You have noticed how each unit you have read is centered around one large idea. Each chapter adds to or enlarges the idea. In this unit we are concerned with production by plants and animals. Yet here we are considering the fact that living things can come only from other living things.

Be patient for a moment and you will soon see that producing food and clothing in this world is a problem of reproduction.

A farmer's job is mainly to encourage the reproduction of his plants and animals. When people speak of conserving our forests and our wild plants and animals, they are thinking of encouraging reproduction of the living things they want and discouraging the reproduction of those which are harmful. In the same way, reproduction on the farm is really a double problem:

1. Encouraging the reproduction of animals and plants we want.

2. Discouraging the reproduction of those we don't want.

Let us now take a look at the ways living things reproduce.

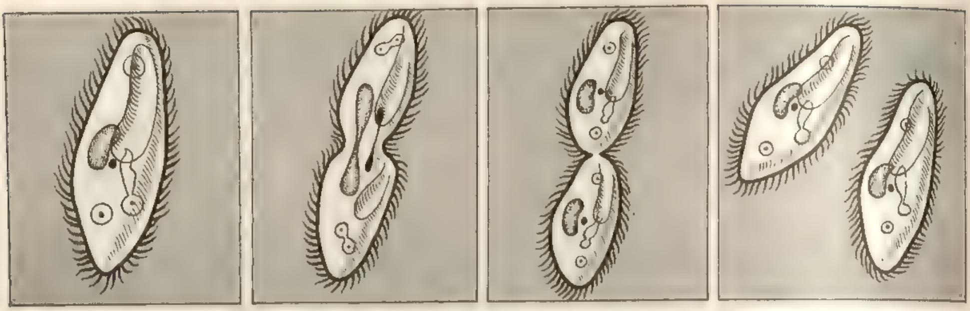
REPRODUCTION BY ONE PARENT

Go to any pond or stream in the late spring, summer, or autumn and fill several jars with water. Add a little mud from the stream and also some of the water weeds you find in the water. When you get home, add about 20 rice grains or 15 wheat grains to the water in the jars. Set these jars aside where it is neither too hot, nor too cold. In a week or so, if you look carefully, you will see tiny white specks swimming about. These are probably single-celled animals, called *Protozoa* (prō′tô zō′ȧ). Probably the one which will be most common will be the *Paramecium* (păr′ȧ mē′shĭ ŭm, Fig. 210). At the end of two weeks, the jar may be swarming with them. How do they reproduce?

AN EXPERIMENT IN REPRODUCTION

If you examine some of these animals under the microscope, you may be able to see one dividing. It begins to pinch in the middle and gradually divides in two (Fig. 210). Two animals are formed from one. Paramecia which have plenty of bacteria and smaller protozoa upon which to feed may reproduce by dividing once every 18 to 24 hours. Because you can see a paramecium with your naked eye, you can even isolate one in a long thin medicine dropper. Then you can check the time it takes one to divide.

There is an important lesson to be learned from this experiment. As you might expect, since two came from one, each daughter paramecium looks like the other. This type of reproduc-



210 *Paramecium dividing. The nucleus is the dark kidney-shaped structure in the animal at the left. What happens to the nucleus?*

tion, in which there is only one parent, is called *asexual reproduction* (ā sĕk′-shŏŏ ăl).

Yet why do the daughter cells look alike? If you were to stain a paramecium with certain dyes, you would be able to see a dark oval structure in its center. This is called a *nucleus* (Fig. 210). All single-celled animals have a nucleus. And, as you remember, almost every cell has a nucleus.

Before a paramecium divides, the contents of the nucleus divide into two equal parts. Each daughter paramecium therefore gets an equal amount of nuclear material. Scientists have found that the material in the nucleus is responsible for the appearance of any plant or animal. Nuclear material therefore determines the appearance of paramecia. Since the two daughter paramecia get equal amounts of nuclear material from one parent, you can see why each paramecium resembles the other.

MAKING SURE WE GET THE SAME KIND

Asexual reproduction is one important method of reproduction used to make one plant reproduce many of its own kind quickly.

You can experiment with asexual reproduction of plants in your own home. Take a geranium plant and cut from it a three-inch branch. Now get a pot of sand. Remove most of the leaves of the three-inch geranium cutting, and stick the cut end of the stem one inch into the sand. The leaves are cut off because the plant doesn't have roots to supply all of its leaves with water.

Be sure to keep the sand moist. In a few weeks, remove the stem cutting from the sand. By this time, it will be a complete plant with new leaves and new roots. And because you took a cutting of part of the old geranium, the new geranium will closely resemble the old one. This is so because each cell in the three-inch cutting has the same nuclear material as cells in the parent plant.

Plants can be grown from cuttings of stems or leaves. You may try the same thing with begonia, rose, willow, forsythia, or matrimony vine cuttings. Or if you have a bryophyllum (brī′ô fĭl′ŭm) plant, take off a leaf and place it in a jar, keeping it moist with wet blotting paper. Soon complete plants will be growing from the notches of the leaf.

You may also grow plants from their fleshy roots or fleshy stems. Place a carrot or a beet (fleshy roots) or a white potato (fleshy stem) in moist sand. Soon these parts of plants will produce a new plant. Thus roots, stems, or leaves can produce a complete plant.

THE FARMER USES ASEXUAL REPRODUCTION

The farmer's livelihood depends upon his success in getting many plants or animals from one. Asexual reproduction is a very useful method for reproducing certain plants. For instance, white potatoes (which are actually thick underground stems) are cut up into pieces, each of which has an "eye" or bud. When these pieces are planted, they will produce complete plants. So when a farmer has a very good, large potato, he can be fairly sure of getting more of the same kind when he plants parts of it.

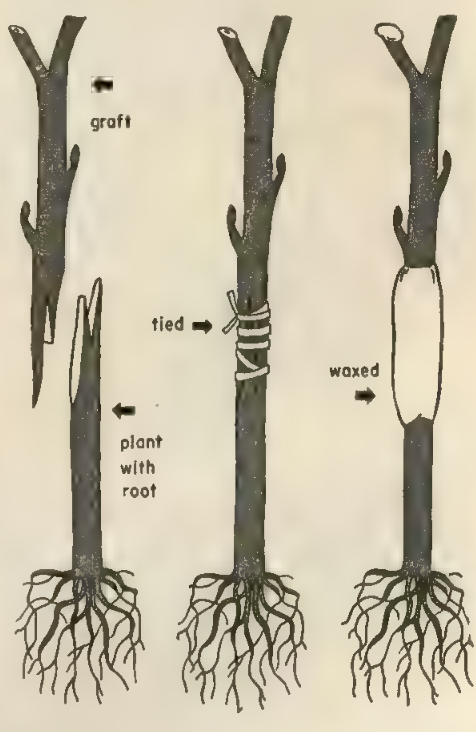
A trip through a farm will show you many examples of asexual reproduction. Here is the strawberry bed. Notice how each strawberry plant sends out runners, which are long stems that grow along the ground. At certain places these runners send roots into the ground. From these roots a new plant will develop.

Here is the farmer's berry patch. The farmer can bend the long arching stem or cane of one of his raspberry plants and cover it with soil. Next spring a new raspberry bush will spring from that place, for the stem will root and send up leaves. This kind of asexual reproduction is called *layering*. You can do the same thing in your garden with roses, forsythia, and magnolias.

Let us watch the farmer in his rhubarb or asparagus patch. Here he digs up a plant and breaks its underground parts into several parts. Then he plants the several parts. Next spring each part of a root will produce a plant. In your garden, you can break up peonies the same way. And you know that the underground parts of grass plants produce additional new grass plants each year. These underground parts can weather severe winters.

GRAFTING

In the fall, let us watch the farmer prepare some apple trees for planting. On his bench are a sharp knife, some soft wax, and some raffia or twine. He has some young crab apple seedlings (young plants) and some Baldwin apple twigs in a box of cool, moist sand. He is going to join the Baldwin twig to the crab apple seedlings. Examine Fig. 211 before you read how the farmer makes his *grafts*. He takes a crab apple seedling with roots at one end and cuts a notch or cleft in it. In one type of graft he takes a Baldwin apple twig and cuts a "tongue" in it. He fits the Baldwin twig tongue carefully into the cleft of the crab apple seedling. Then he winds raffia tightly about this joint and waxes the raffia so the joint doesn't



211 *Simple grafts. Notice how closely both stems are joined.*

dry. He places the seedling with its grafted twig in moist sand in a box which he keeps in his cool cellar. Early next spring when the two have grown together, he will plant the young tree. Before planting it, he will have removed the buds and branches of the rooted crab apple twig so that the grafted tree grows only from the Baldwin twig.

In *grafting*, a twig of one fruit tree is set into the seedling of another fruit tree whose roots are hardy and are not easily killed by cold or disease. In this case, the Baldwin was grafted to a hardy crab apple. A grafted twig always bears the fruit of the tree it comes from.

Why doesn't the farmer plant a cutting from a Baldwin tree? The best reason is that cuttings of Baldwin apple trees do not make root easily. Why not plant a Baldwin apple seed? The answer is that seed from a Baldwin tree may not produce a Baldwin apple tree. We shall need to study how seeds are formed in order to see why this may happen. But the farmer can be sure that if he grafts a Baldwin stem into another stock, he will certainly get a Baldwin tree.

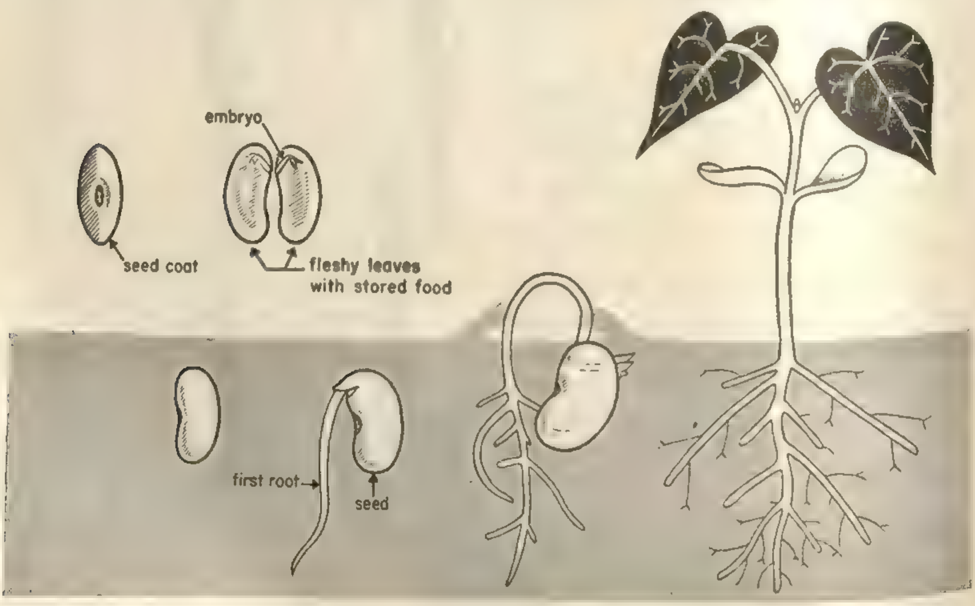
REPRODUCTION BY TWO PARENT PLANTS

What is in a seed that enables it to produce a complete plant? Let us dissect a seed to find out.

SEEDS

Soak a handful of bean seeds in water overnight. In the morning remove the seed coat from one of them. The seed coat normally protects the seed against drying out (Fig. 212). Now separate the two fleshy halves of the seed. Each half is a leaf, which contains the stored food upon which the young plant will grow. Examine the young plant, which is called the *embryo* (Fig. 212). Can you see the embryo's small leaves and its beginning of a root?

The next step is to plant the other seeds in moist sand or sawdust. Every



212 *The growth of a bean seed. Where does the embryo get its food?*

three days dig one out and make a drawing of it. Do your notebook drawings look like those in Fig. 212? From these investigations, you can see that a seed is an embryo plant with its stored food, protected by a seed coat.

Much of our food consists of the seed embryo and its stored food (such as in beans and peas). The seed's stored food is highly nutritious for human beings and animals, as well as for the embryos. Fruits, which contain seeds, are also valuable human foods. One of the farmer's jobs is to make sure that his yield of seeds and fruits is high.

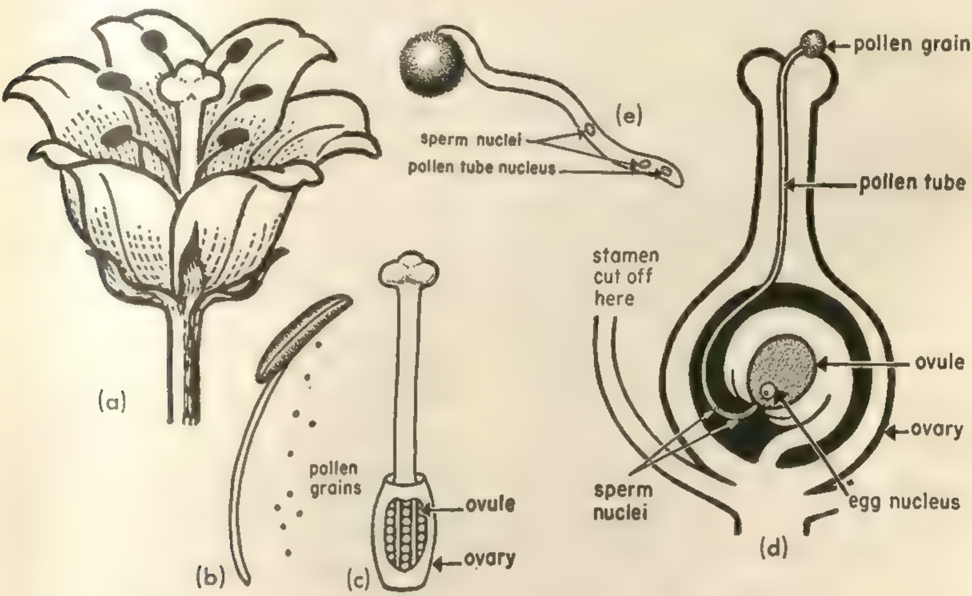
To kill the fungi and insects which attack the flowers of his fruit trees, the farmer sprays his trees several times a season. He cultivates his fields to kill weeds which may interfere with the flowering plants he wants to grow. If he wants seeds, he must get the plant to grow well and produce flowers.

THE FLOWER—BASIS OF PLANT REPRODUCTION

Examine a large, bright, showy flower like that of the apple tree or lily. If you have none available, examine the diagram carefully before you continue reading (Fig. 213).

If you push the petals of a lily apart, you will find six long slender pinlike structures called *stamens* (stā′mĕnz, Fig. 213). The top of the stamen may be dusty with yellowish *pollen grains*. If you examine one of these pollen grains under the microscope, you will find they look like those in Fig. 213.

Now examine the thick central structure of the flower. This is the *pistil* (Fig. 213). The top portion of the pistil is sticky; its function is to catch and hold the pollen. The bottom portion is thickened; this is the *ovary* (Fig. 213). In it, you will find small oval bodies that will eventually form the seeds. These are called the *ovules*.



213 *A typical flower:* (a) *blossom showing pistil surrounded by stamens and petals;* (b) *stamen with pollen grains falling from it;* (c) *pistil;* (d) *pollen tube* (*formed from pollen grain*) *growing down pistil to ovule; sperm nuclei travel down pollen tube and one fertilizes the ovule;* (e) *pollen tube forming from a pollen grain.*

214 *The seeds of a dandelion. How are they spread? (American Museum of Natural History)*

FERTILIZATION

Seeds cannot be formed unless the contents of the pollen unite with the contents of the ovule. What is in the pollen grain and ovule that is responsible for the formation of a seed?

Scientists have found that both pollen and ovule contain nuclei (p. 315). In the pollen, we find male or *sperm* nuclei; in the ovule, a female or *egg* nucleus. Before a seed can be formed, the sperm nucleus must unite with the egg nucleus (Fig. 213).

This is the way the sperm and the egg get together. The pollen grain is carried by wind or by insects to the pistil. There the pollen produces a long *pollen tube*. This pollen tube carries the sperm nucleus to the egg nucleus in the ovule. When the pollen tube reaches the ovule, it penetrates the ovule and the contents of the pollen tube and ovule mix. There the two nuclei fuse. Scientists call this fusion of sperm and egg nuclei, *fertilization*. Once this fertilization happens, the seed begins to develop.

Now in each ovary, whether in a bean or an apple, there are many ovules. These are fertilized by many pollen grains and form many seeds. Also while the seeds are forming in the ovary, other parts of the flower develop around them and form the fruit. So the apple (fruit) is really a ripened ovary (plus other flower parts).

SPREADING SEEDS FAR AND WIDE

Animals, of course, can move about, but plants are rooted in one place. How then do plants spread to new soil, to new places?

You must have at one time or another taken up the fluffy head of a dandelion and blown it into the wind (Fig. 214). The next time you do it, notice that each dandelion parachute has a seed attached to it. And the wind carries each seed to a new place where it may grow. Have you ever combed cockleburs out of your dog's hair? Each one of these hitchhikers contains seeds. Your dog has helped spread cocklebur seeds. Or have you ever found them attached to your clothing?

By this time you may have guessed that each plant has its own way of spreading. The fruits of some plants are winged and are spread by wind. The seeds or fruits of other plants drop into streams and are carried along to new locations. Coconut seeds are generally spread in this way. Some plants like the cocklebur and the beggar-ticks are spread by animals. Birds, as a rule, spread a good many plants such as cherries. They eat the fruit and scatter the pits, which contain the seeds of the cherry tree.

MAKING SURE OF POLLINATION

If seeds are to be formed, *pollination* must take place; that is, the pollen formed by the stamen must reach the pistil. For most crops, the farmer need not worry about this at all. Wheat and oats are self-pollinated; that is, the plant's own pollen falls on its pistil. The wind may help the pollination of corn by carrying the pollen from the stamen (the tassels) to the pistil (the silks). Because the tassel is so much higher than the silks, the pollen usually falls on the silk.

The farmer's fruit trees, however, need to be pollinated by bees. Many farmers keep beehives in their orchards for this reason. The bees take some of the pollen for food. But in their flight they often carry the pollen of one flower to the pistil of another. When the pollen is brought from a different flower, *cross-pollination* occurs.

Now you can figure out why farmers prefer to get their young fruit trees by grafting rather than by planting seeds. Fruit trees are cross-pollinated. The seed in a Baldwin apple may have come from pollen brought from a McIntosh flower to the Baldwin flower. In this case, the McIntosh pollen would have fertilized the ovule of the Baldwin.

Scientists know that the characteristic taste and color of fruits are determined by materials in the sperm nucleus and egg nucleus of the new plant. Therefore, the seed formed from the fusion of a pollen (male) nucleus of a McIntosh and the female nucleus of the Baldwin would have the characteristics of both kinds of fruit. It would grow into a tree that would be neither Baldwin nor McIntosh. Since there is so much uncertainty about the origin of apple seeds, grafting is a surer method of producing fruit trees. In grafting, the farmer uses a twig from the original tree (let us say, a Baldwin). Since the same nuclear material found in the original tree is present in the twig he uses for grafting, he is certain that the new tree will be the same as the parent. In this way, the farmer can control the kind of fruit produced. He does not leave it to chance.

ASEXUAL AND SEXUAL REPRODUCTION

There is an important difference between offspring from just one parent and offspring from two parents. Offspring of one parent, as you remember, are a result of asexual reproduction. One nucleus is responsible for the characteristics of both offspring. Thus a cutting of a geranium has the cell nuclei of its parent plant.

In *sexual* reproduction, two parents are involved. Two parent nuclei were responsible for the characteristics of the offspring fruit tree. Thus, if a male nucleus from a McIntosh apple tree fuses with the female nucleus of a Spy apple tree, the young tree will have the characteristics of both.

In the asexual reproduction of, say, a Delicious apple tree, 50 of its twigs may be used in grafting. They will grow eventually into 50 Delicious apple trees, each like the others. But take 50 Delicious apple seeds and you have another story. Instead of one kind of apple there might be 50 kinds, not one of them a true Delicious.

Each seed is a result of sexual reproduction by a male part of a plant (stamen) and a female (pistil, Fig. 213). The pollen may have come from a Baldwin, McIntosh, Greening, Spy, or even a wild apple tree. Therefore, a seed may have some of the characteristics of any of these, depending on which pollen reached the pistil.

In asexual reproduction, however, all the offspring have the characteristics

of the one parent, since only one parent produced it. In sexual reproduction, the offspring may differ from each other in many ways because they come from two parents. They may resemble one or the other, or both.

REPRODUCTION BY TWO PARENT ANIMALS

Although many plants can be reproduced asexually, only a few animals reproduce this way. The Protozoa, like paramecia, reproduce asexually by dividing; so do some other simple animals. Even the Protozoa and other simple animals which reproduce asexually also have methods of sexual reproduction. But most complex animals reproduce only sexually; that is, they have two parents. A frog is a good example.

REPRODUCTION IN ANIMALS—THE FROG

In the early spring, make a search for frogs' eggs in the small ponds and streams. Probably the eggs will have already been fertilized; that is, a sperm produced by the male will have fused with each egg produced by the female frog. In the plant, you will remember, the male nucleus fused with the female nucleus during fertilization. In the frog, as in other animals like it, the male cell (the sperm) fuses with the female cell (the egg) during fertilization. Fusion of sperm and egg produces a fertilized egg.

Sperm cells are microscopically small. Under a microscope, they look like those in Fig. 215. By moving their tails they swim rapidly until they enter an egg, which is many times larger. The egg is surrounded by a protective jelly. It is also filled with whitish yolk which will be the food of the developing frog embryo.

It is interesting to watch a frog's fertilized egg develop. With a good hand lens, you will be able to see that the fertilized egg begins to divide in half (Fig. 215). Every half hour there may be a division until the original fertilized egg is a ball of cells. In about a week this ball of cells develops into the shape of a young tadpole.

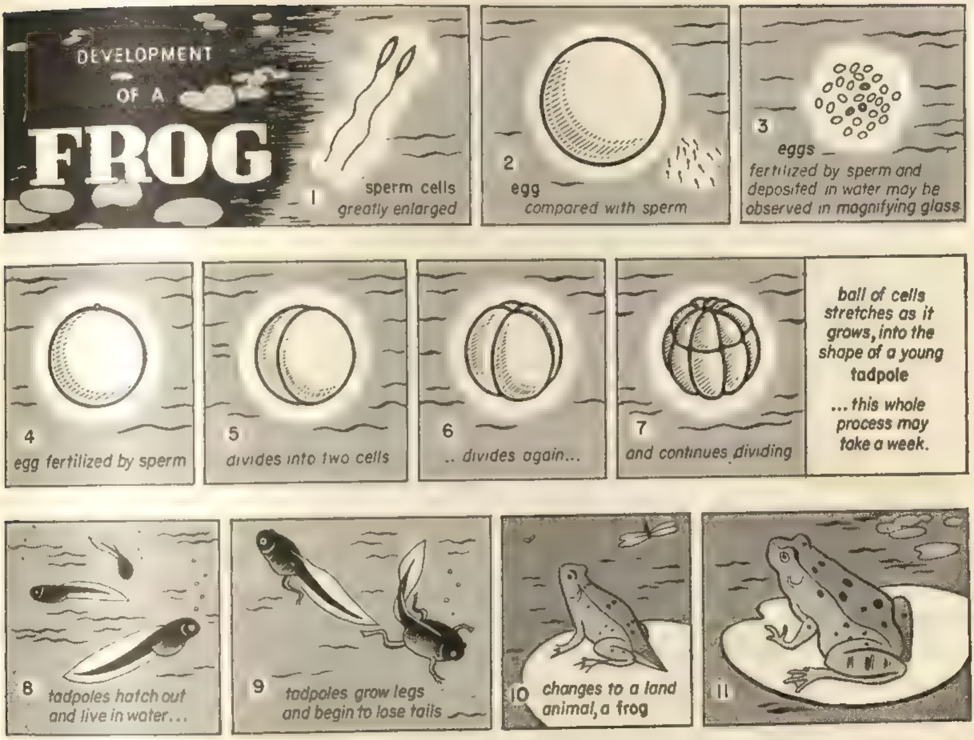
The tadpole hatches out of the jelly and begins to feed on water weeds. It is a water animal breathing by means of its gills and swimming by means of its tail. Many tadpoles are eaten by fish and water birds and frogs. Those that survive begin to lose their tails and soon the legs appear. Thus a water animal, a tadpole, changes to a land animal, a frog (Fig. 215). But it must remain in a moist environment, for it breathes through its skin as well as with its lungs.

BREEDING BIRDS AND MAMMALS

There are some frog farms where large bullfrogs are bred for market. Most farmers breed birds like chickens, ducks, geese, turkeys, and mammals like cattle, pigs, horses, sheep. In order to get the best production through reproduction, the farmer must give his animals good food and clean shelter.

It will be interesting to observe fertilized hens' eggs in the classroom. You may be able to buy fertilized eggs at a grocery or a chicken farm. The eggs need warmth for development. Have you seen hens sitting on eggs to supply this warmth? On large farms, an incubator will do the job. In the laboratory, you may also use an incubator.

Take the fertilized eggs to the school laboratory and put them in an incubator at 104° Fahrenheit. Put a pan of water in the incubator to keep the air moist. And be sure to turn the eggs each day. This will enable the embryo to develop normally.



215 *Next spring, get some frogs' eggs and watch them develop.*

As soon as you bring your eggs to the laboratory, open one of them. The shell protects the eggs against drying out. The egg white and the yolk which you see serve as food for the embryo. On the yolk, you cannot fail to notice a whitish spot. This is the place of the developing embryo. You can see that the microscopic sperm could not possibly penetrate the hard egg shell. The union of the sperm with the egg in birds takes place in the hen's body before the shell is formed around the egg.

Every day or so, take out an egg and open it carefully. At the end of three days, the chick will appear as the one in Fig. 216. Its heart will be beating. At five days, it will look like Fig. 216. By careful observation over several days, you will get a good picture of the developing chick till at last on the 21st day, it pecks through the egg shell.

Don't feed the young chick. It has enough stored food (yolk from the egg) in it for 48 hours. Keep it warm and in two days it will be an active little bird, as it begins to feed. Not all birds are like the chick that is born almost ready to feed itself. Some, like the robin, born helpless and without feathers, depend on the parents for food.

MAMMALS ON THE FARM

A developing chick is protected by its egg shell. When it hatches, it is just about ready to take its part in life. But the mammals on the farm, the cattle, pigs, goats, sheep, dogs, or cats are even better protected. For both fertilization and development take place inside the mother. They are born alive

and after birth the mother cares for them and protects them.

All mammals feed their young milk from their milk (mammary) glands. These mammary glands are one of the distinguishing structures of the mammals.

Because mammal young are protected and nourished by the mother, the farmer's job is to see that plenty of food is within reach of the mother. Soon the mammal young can be turned out to pasture or given prepared food.

WHY DO ORGANISMS PRODUCE THEIR OWN KIND?

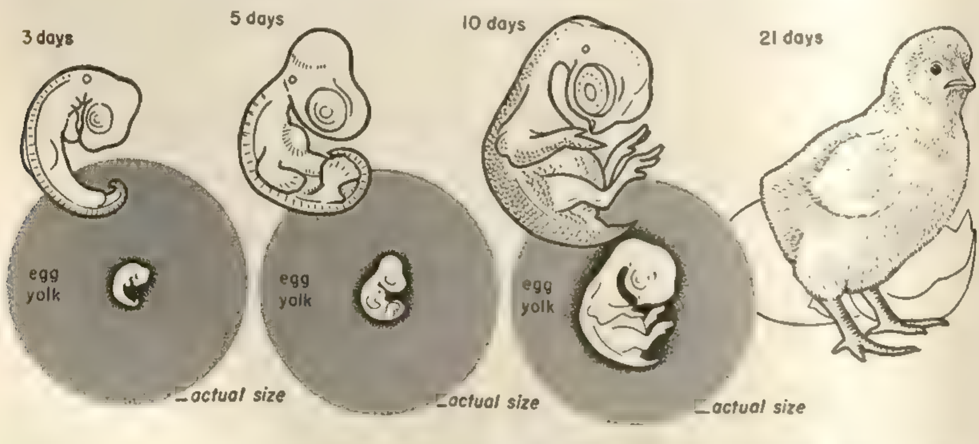
Notice that we can expect a hen's egg to produce a chicken, not a duck, a goose, or a bald eagle. A frog's egg produces a frog, not a salamander or a toad. Horses produce horses, not elephants or sheep. Like produces like. Why?

Recall that the contents of the nucleus of the paramecium determine the structure of its offspring. Scientists also have discovered that the contents of the nuclei of the sperm and egg determine the structure of all animal offspring. Thus we know that a male frog and a female frog can produce only frogs. The nucleus of the sperm cell contains the materials which determine the structure of the frog as does the nucleus of the egg. In all sexually producing plants and animals, the nuclei of sperm and egg carry the materials which determine the structure of the living thing. Thus the offspring is the same kind of animal as the parents.

Another way of putting all this is to say that the offspring inherits traits from its parents. Thus a colt has the traits of its parent horses, a robin those of its parent robins.

THE JOB IS NEVER DONE

In this chapter, you have sampled some of the methods by which plants and animals reproduce. In other science courses, you will learn more about reproduction. However, you have enough information here to understand how production of food through reproduction takes place on the farm. The farmer's job is one of the most healthful, one of the most necessary, one of the most satisfying jobs in this modern world. Have you thought of it as a lifework for yourself?



216 *Development of a chick. Get some fertilized hens' eggs and incubate them. Examine one of them every two days or so.*

GOING FURTHER

1 *Asexual reproduction in plants.* Grow a carrot plant from a carrot root, a beet plant from a beet root, an onion plant from a bulb, a geranium or begonia from a cutting. Place the carrot, beet, onion, or the cuttings in moist sand or in a small jar of water.

2 *Egg development.* In the spring, collect frog or salamander eggs (Fig. 215). Allow some to develop at room temperature. Keep others at a colder temperature (in the icebox, if possible). Which develop faster? Keep a time record of their progress. Make complete drawings of the development of eggs, into tadpole, into frog, or into salamander.

3 *Words are ideas.* Can you use these words in a sentence which will give their meaning? Use the glossary.

flower	egg	layering
pistil	sperm	sexual reproduction
anther	fertilization	asexual reproduction
stamen	development	pollination
ovary	cutting	cross-pollination
seed	grafting	embryo
fruit		ovule

4 *Put on your thinking cap.*

1. Why is one Baldwin apple tree very similar to another?

2. Why are potato seeds rarely planted?

3. A breeder of flowers wants to be certain that he gets only seeds that produce a yellow iris. In order to do this, he must get the pollen of a yellow iris on a pistil of another yellow iris. How can he accomplish this? Write out a method which you think will work and give it to your teacher to read.

5 *Test yourself.* In your notebook, copy the following sentences. Put a T next to the statement if it is true, and an F if it is false. Give reasons for your judgment. Do not mark this book.

1. Grafting is a form of sexual reproduction.

2. If we wanted to get a single-celled animal that was like the parent, we should try to get the parent to reproduce sexually.

3. Seeds are always the result of cross-pollination.

4. A male frog and a female frog can produce toads.

5. The developing chick gets its air through the shell.

6. A male pigeon mated to a female pigeon can produce only pigeons.

7. A male rat mated to a female rat can produce mice.

8. A male cocker spaniel mated to a female cocker spaniel may produce fox terriers.

6 *Adding to your library.*

1. In Unit VII of *Exploring Biology* by Ella Thea Smith (Harcourt, Brace, 1949) you will find a clear, interesting, and well-illustrated discussion of reproduction in plants and animals.

2. In *Human Growth* by Lester F. Beck (Harcourt, Brace, 1949) you will find a simple account of reproduction and development. The book is clearly written and well illustrated.

3. *The Wonder of Life* by Milton I. Levine and Jean H. Seligman (Simon and Schuster, 1941) is another introduction to the facts of early development.

CHAPTER 18

NEW FORMS FROM OLD

What would you have done in Seth Wright's place? Here he was looking at a lamb just born. Nothing strange in that! It is the farmer's business to produce food through reproduction of his animals. But this particular lamb was a strange animal, indeed. For instead of the four long legs most lambs have, this lamb's legs were very short. As a matter of fact, it looked a little like a dachshund.

"Might be useful at that," Seth Wright might have thought to himself. "Sheep with short legs won't jump over fences so easily." Besides, it was a new variety of sheep. Seth Wright set himself the job of getting a breed of sheep with short legs.

SECURING PURE BREEDS

You have heard of breeds of horses, breeds of cattle, breeds of dogs. A breed or a variety is a kind of animal which differs from others of its kind by one or more distinguishing characteristics. For instance, you can easily distinguish most breeds of dogs; there is a clear difference between a collie and a bulldog or between a spaniel and a Great Dane. There are different breeds of cows, chickens, sheep, horses, wheat, oats, and corn. Each breed or variety has certain definite traits.

How could Seth Wright get a breed of sheep with the trait of short legs? He could try mating a short-legged sheep with a long-legged sheep. He expected that the offspring might be short-legged, long-legged, or medium-legged.

Suppose one offspring of this mating were short-legged and of the opposite sex from the first short-legged lamb? Then the problem is easy. Seth Wright would wait for this short-legged offspring to grow up. Then he would mate it with the original short-legged sheep.

Seth Wright was doing what all breeders do. First, they select the animal or plant with the trait they want. Second, they mate the animal or plant with others. Then when they get other offspring with the desired trait, they mate only offspring having the desired trait. This is called *inbreeding*. In inbreeding, only animals with the desired trait are mated. This inbreeding is kept up, till a breed of animals or plants with the desired traits is produced. Can you apply this method to the following problem?

217 *These are the famous longhorn steers, a variety now rapidly vanishing.* (*U.S. Department of Agriculture*)

GETTING RID OF THE LONGHORN

Longhorn cattle, you can see for yourself, are dangerous animals (Fig. 217). The animals fight and gore each other; they are sometimes hard to handle. When shipped to market, they may and do gore each other in the boxcars. Besides, shorthorn cattle are heavier; they have more beef. To have a breed of shorthorns would be the ideal thing. How would you go about developing such a breed?

ARE ACQUIRED TRAITS INHERITED?

Possibly you would decide to cut off the horns and mate two animals you had made hornless. Any cattleman would tell you that wouldn't work. For they themselves cut off the horns to make the cattle less troublesome to handle. Yet the offspring of these cattle develop long horns.

Cattlemen know that the trait of long-hornedness is inherited. In human beings, eye and hair color, shape of face, nose, ears, and height are among the traits inherited.

Scientists call any trait which is not inherited an acquired trait. For example, the hornlessness gained by cutting off horns is acquired. It cannot be passed on to the offspring. A man's knowledge of mathematics, or music, or science is acquired. His offspring, therefore, must go through the business of learning mathematics, science, or music.

Here is more evidence. Certain Chinese groups bound the feet of young girls to keep the feet small. Chinese girls, however, were not born with smaller feet. Members of the Ubangi tribe in Africa put plates under their lips to make the lips large. However, Ubangi offspring are born with normal lips.

August Weismann was a scientist who wondered whether acquired characteristics were inherited. In the late nineteenth century he began investigating. He took some young mice and cut off their tails. When they became adult mice, he mated them. Would the offspring have tails or would they be tailless? They all had tails. He cut off the tails again. He mated them. Again the offspring were born with tails. And so this went on for many generations.

Weismann concluded from this experiment and other facts that acquired characteristics are not inherited (Fig. 218).

APPLYING THESE FACTS TO YOURSELF

No doubt you have heard the saying: "Like father, like son." This is a short way of saying that the son inherits his father's characteristics. Is it true?

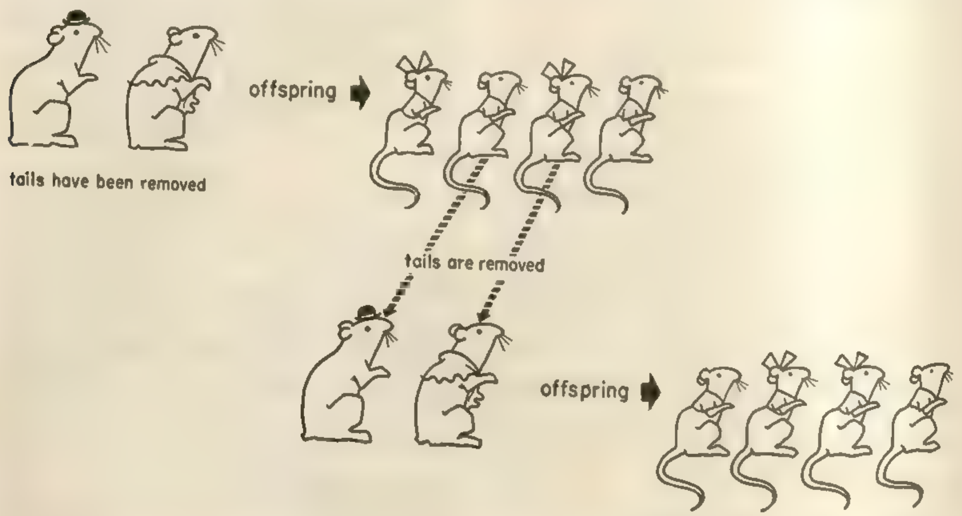
You can see how physical features such as eye and hair color, shape of face, size and shape are inherited from both parents. But does the child inherit his parents' behavior? For instance, does he inherit their hatreds, their likes and dislikes, their prejudices, their religion, their citizenship in any country?

Think a moment and you will see that all these are acquired characteristics and are taught to children. For instance, children born in the United States of parents who were born in France are not French but Americans. In general, they act like Americans, except when the parents teach them some French customs. Characteristics that are not inherited are acquired; they are learned from parents, friends, teachers, radio, movies, books, newspapers. These acquired traits cannot be passed on to offspring. At present, it is recognized that only those characteristics determined by the materials in the nuclei of sperm and egg cells can be passed on to the offspring.

MUTANTS

There are facts available which help us solve our original problem: How can we get cattle with short horns if we cannot get rid of the long horns by cutting them off? The answer is that we must wait for an accident in inheritance. Have you ever seen a white crow (Fig. 219) or a white robin? They are called albinos. A white elephant is also such an accident in heredity.

Naturally such accidents are rare. Breeders have called them sports. Scientists call them *mutants* (mū′tănts). A mutant is an animal or plant which differs from the parents in a given new trait that can be inherited. As you remember, scientists have discovered that the contents of the sperms and eggs are responsible for such traits as short-hornedness (p. 320). When a



218 *A picture summary of Weismann's experiment. What is your conclusion?*

219
A white crow. He is the result of an accident in heredity. (Buffalo Museum of Science)

mutation occurs, the contents of the nucleus of a sperm or egg of the animal have been changed somewhat, thus producing the new trait. Scientists do not know yet how those changes occur.

How can you test whether a new trait is a mutation or an acquired trait? Breed the animal for several generations. If the trait reappears many times during constant breeding, it is a mutation. The white rat which you have in the school laboratory is a mutant. It first appeared in the offspring of two gray rats. When it was mated to another white rat, more white rats were produced. White fur was, therefore, a mutation, not an acquired characteristic. If it had been acquired, let us say by bleaching, it would not have been inherited.

By now you have probably guessed that a mutant shorthorn was found in a herd of longhorns. And the breeder who was interested in getting more shorthorns followed the principles of breeding:

1. He selected the trait he wanted. In this case, it was a short-horned animal, a mutant.

2. He mated his short-horned animal with other cattle until another shorthorn was produced.

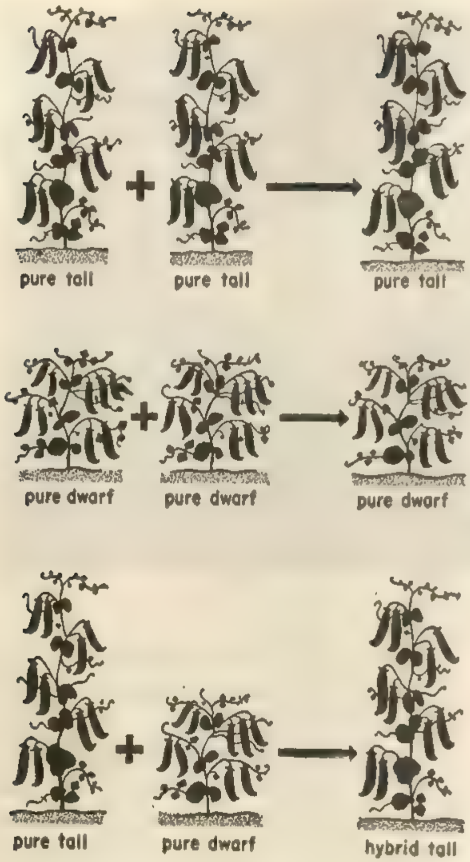
3. Thereafter he mated animals with the trait of short-hornedness. This inbreeding produced offspring with the trait desired.

And our breed of shorthorns arose in just that way.

WHAT CHARACTERISTICS CAN BE INHERITED?

To answer this important question, we need to go back to 1850 to a monastery in Brünn, Austria. There Gregor Mendel, a monk, is working in his garden. What is he doing? Mating pea plants. Why? To discover the laws of inheritance. His work is the basis for all that scientists know today about inheritance of traits.

Mendel had worked for two years producing a pure line of tall (six-foot) pea plants and another of dwarf (one-foot) pea plants. What is a pure line? Whenever Mendel mated two pure tall plants, the offspring were always tall (Fig. 220). Since the offspring were al-



220 *Illustrating one of Gregor Mendel's experiments. What is the result of mating a pure tall pea plant with a pure dwarf plant?*

ways tall, the parent plants were pure-line tall plants. When he mated two pure dwarf plants, the offspring were always dwarf. The parent dwarf plants were, therefore, pure-line dwarf plants. The nuclei of the pure-line plants Mendel mated had only factors for the trait tallness or dwarfness, but not both. In Mendel's pure dwarf plants, for instance, the nuclei had the characteristics for the trait dwarfness. A pure line can be depended upon to produce in the offspring the characteristic for which the pure-line parents were bred.

When Mendel mated a pure tall pea plant with a pure dwarf, all the offspring were tall. No matter how many times pure talls were mated with pure dwarfs, all the offspring were tall. Mendel called a trait shown in the offspring of two different pure lines the *dominant* trait. In pea plants, tallness was a dominant trait. He called the one that is hidden, a *recessive* trait. In pea plants, dwarfness is recessive.

There are many interesting dominant traits in man's inheritance. For instance, brown or black eye color is dominant over blue eye color. Blue eye color is recessive. This is one reason, though not the only one, why most people have dark eyes. Dark hair color is dominant over blond. In order to be blond-haired (light blond hair) or to have a recessive trait appear in the offspring, the dominant trait must be absent in the offspring. Remember this refers only to traits in which one is clearly dominant and the other is recessive; such as tallness and dwarfness in pea plants.

However, since Gregor Mendel's time, other scientists have discovered that in the inheritance of certain traits there is no dominance. For instance, when a pure red-flowered four-o'clock is mated with a pure white-flowered four-o'clock, the offspring are neither red nor white. They are pink-flowered. Neither red nor white is dominant; each factor plays a part in producing the color pink.

HYBRIDS

You know now that when a pure-line tall and a pure-line dwarf pea plant are mated, the offspring are all *tall*. But the tall offspring are not pure line since they must have both the determiners for the dominant and recessive trait within them. Such plants are called

hybrids. A hybrid has the determiners for two different traits (for example, the determiners for tallness and dwarfness in garden peas). Pink four-o'clocks are hybrids. They have the determiners for red and white, neither of which is dominant. A pure black-haired male parent and a pure blond-haired female parent will have dark-haired children. But the children will be hybrids since they will have the determiners for dark hair color and blond hair color.

APPLYING THE FACTS

Many of the traits you will deal with are either dominant or recessive, like those affecting height in garden peas. But some, like color in the four-o'clocks, are neither dominant nor recessive.

The facts about dominant and recessive traits and hybrids are most useful to plant and animal breeders. They are tools which breeders use to produce stronger plants and animals (Fig. 221). For instance, some varieties of the wheat plant, upon which the world depends for its bread, are unable to live through a hard winter. Plant breeders found a variety of wheat which was winter-hardy; that is, it could stand extremely cold weather with little moisture. It was mated with a nonhardy wheat having other good traits. The hybrid resulting from this mating was winter-hardy. Winter-hardiness proved to be a dominant trait.

Scientists could now predict that matings of pure winter-hardy with any nonhardy plants would produce winter-hardy plants. From the same kind of experiment it was learned that the trait of short horns is a dominant trait in cattle. Scientists could predict that a pure shorthorn bull mated with a longhorn cow would always produce shorthorn offspring.

221 *These hybrid cattle were bred in Colombia, South America. Their thick hides enable them to withstand the bites and stings of certain insects. (Standard Oil Co. (N.J.))*

Knowing whether a trait is dominant or recessive enables scientists to predict the kind of offspring they will get. This enables them to carry on breeding experiments which yield plants and animals with desired characteristics.

THE DISCOVERY OF GENES

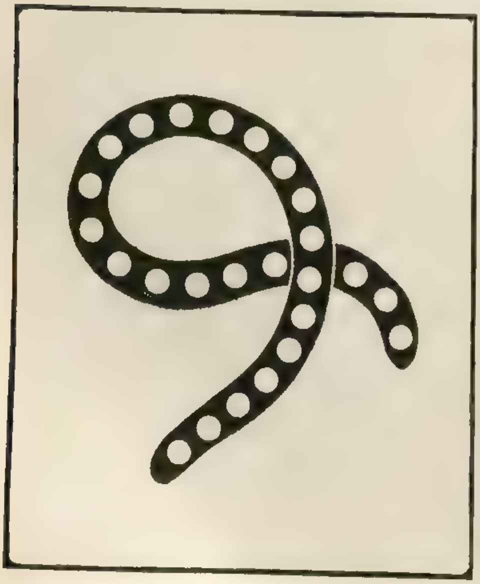
You have probably been wondering what is really responsible for these traits—tallness, dwarfness, blond hair color, and short-leggedness in sheep. Since 1900, scientists have been on a hunt for the factors responsible. We may summarize the result of years of study in this way. The determiners responsible for traits that are inherited are called *genes* (jēnz). Genes are found in certain rod-shaped bodies called *chromosomes* (krō′mȏ sōmz, Fig. 222). Chromosomes are found in the nuclei of cells. As yet, scientists do not know very much about the make-up of genes and chromosomes.

As you see in Fig. 222, the genes are thought to be lined up in the chromosomes like beads on a string. When the genes are changed in some way as yet unknown, mutants are produced. Thus the first short-legged sheep appeared as a result of change in the genes which govern the length of the sheep's legs.

A pure, tall pea plant has genes for tallness, none for shortness. A pure dwarf pea plant has genes for dwarfness, none for tallness. The hybrid has the same number of genes for tallness as it has for dwarfness. However, since tallness is dominant the hybrid will be tall. We say, therefore, that the gene for tallness is dominant.

The breeder's job can be summed up as a search for desirable genes. By desirable genes are meant those which benefit man. They may not benefit the animal or plant. For instance, from a steer's point of view long horns are desirable for they are a means of protection against other animals. Therefore, the desirable genes (from the

222 (Left) *A diagram of a chromosome showing genes as they are thought to be arranged.* (Right) *A photograph of whitefish chromosomes in the act of separating from each other into different cells.* (*Photograph from General Biological Supply House*)



223 *Compare the large newly bred blueberries on the left with the ordinary ones on the right. How might those on the left have been produced?* (*U.S. Department of Agriculture*)

animal's point of view) are those for long-hornedness. But from man's point of view, desirable genes are those for short-hornedness. Breeders watch for mutants bearing desirable traits and use these mutants to start a new breed.

GENES AND ENVIRONMENT

You may have gotten the impression that traits are determined only by genes. However, you can see that the presence in a cow of genes for high milk production may not necessarily result in high milk production. In order to get the best milk production the cow can yield, the animal must be well fed and well cared for. That is, she must have a good environment as well as the genes for high milk production.

A baby may have genes for the production of good straight bones. Yet without a sufficient amount of vitamin D, these bones may not be straight because the baby may get rickets. Again the environment, in this case vitamin D, is necessary for the inherited trait to show itself. A corn plant with genes which will result in the production of red ears (red corn grains) may not produce red ears unless it is grown in bright sunlight.

Many such cases have been discovered by scientists. It is recognized that, although it is the gene which is primarily responsible for the trait, a certain environment is necessary to bring the trait out. Another way of stating it is to say that the gene plus the environment is responsible for the expression of certain traits in the offspring.

A COUNTY FAIR

Anyone who is interested in breeding new forms of plants or animals should visit a county fair. It is fun and it is interesting. On the serious side, you will find exhibits of the best stock and the best plants in the county. Let us take a tour over the fairgrounds.

Here are blueberries, twice the size of any grown before (Fig. 223). Look

at the large apples, the seedless grapes, the peaches, and other fruits grown on the farm. There are so many things to be seen.

Here is a cow (Fig. 224 top) that looks like any other cow. But look at her championship record. She produces about 30,000 pounds of milk per year. In the year 1900 the best record was only 18,000 pounds. What a prize package of desirable genes that cow is!

Here is as fine a pair of mules as you would see anywhere (Fig. 224 center). Truly, they are a product of the breeders' art; mules result from mating the horse with the donkey. These two mules are strong, healthy, and bred to be work animals, and they look as if they can outwork any horse of their own size.

Look at this immense Berkshire sow (Fig. 224 lower left). She can turn food into ham and bacon faster than other sows. What a far cry from the small scrawny pig from which she and her kind originally started! And let us not forget the hen over there (Fig. 224 lower right). She looks like an ordinary hen, but notice her egg-laying record: 288 eggs in her first year—almost one a day.

Yes, the county fair is the place to see a collection of some of the most desirable plants and animals; the result of hard, patient work in breeding to increase and enrich the nation's food supply.

BOOKS YOU OUGHT TO HAVE

The United States Department of Agriculture publishes a report of its work each year. Copies are free to farmers, and may be purchased by others for a small price. These reports tell of the work of the scientists who are breeding new forms.

The Yearbooks (as they are called) for 1936 and 1937 are especially interesting. In them, you will find the results of breeding new forms of animals and plants, from bees to foxes, from broccoli to corn. The mere listings of the new forms to be found in these governmental reports would take several pages. The stories behind these new forms of life are the exciting stories of the search for more desirable plants and animals.

These books show you how scientist-breeders produce more and better foods, and material for clothing, shelter, and medicines. Reading them, you will realize that there is an unbroken line which stretches from the scientist who is even now at work breeding an improved plant or animal—to you. For breeding new forms from old means breeding for better living.

GOING FURTHER

1 *Rat experiment.* If your school laboratory has white (albino) rats and hooded black rats, mate the two kinds. What will the offspring be? When you get them, determine which characteristic is dominant.

2 *Corn experiment.* Get an ear of corn with black and white, or red and white (really yellow) corn grains. Determine the number which are black, the number white or yellow. Which characteristic is dominant? If you have three times as many black or red grains as there are white, what characteristics may the parents have possessed?

3 *Words are ideas.* Can you use these words in a sentence which will give their meaning? Use the glossary.

inheritance	variety
mutant	selection
acquired trait	recessive
inbreeding	dominant
genes	chromosomes

4 *Put on your thinking cap.*

1. Farmer A has a 100-acre farm. Farmer B has a 200-acre farm. Both are

224
Record-producing animals. They are fine packages of genes. (All photographs from U.S. Department of Agriculture)

dairy farmers. How can Farmer A produce nearly as much milk as Farmer B? Assume both can get enough feed.

2. In a family we know, both parents are brown-eyed. They have four children—two of them with blue eyes. What genes did the parents have? Why?

3. How true are these common sayings:
"Like father, like son."
"You can't make a silk purse out of a sow's ear."

5 *Test yourself.* In your notebook, place a T in front of the statements that are true and an F in front of the statements that are false. In answering these questions, think over the effects of heredity and those of environment. Do not mark this book.

1. In animals inbreeding is necessary to develop a variety from a mutant form.

2. It has long been known that acquired traits can be passed on through heredity.

3. If a dog's tail is chopped off, its puppies will have no tails.

4. Ability to speak a language is an acquired characteristic.

5. A white crow is an example of a mutant or sport.

6. Sometimes a mutant characteristic is dominant.

7. Traits that are inherited are always due to genes in the eggs or sperms of the parents.

8. If a red variety of cattle bred with a white variety produced a roan (rust) color, the red color would be called dominant.

9. Genes are located in the chromosomes of cells.

10. A hen hatched from an egg of a good egg-laying variety of chicken is likely to be a good layer.

6 *Adding to your library.*

1. From the United States Department of Agriculture get the Yearbooks for 1935, 1937, and 1947. These books—about 1,000 pages each—are crammed full of information about breeders and special breeds of plants and animals.

2. *You and Heredity* by A. Scheinfeld, Stokes, 1939. This is most interesting reading about the inheritance of man's traits. It discusses inheritance of traits such as baldness, musical talent, red hair, and many others.

CHAPTER 19

USING SOIL WISELY

From your study of American history, you remember Patrick Henry's famous speech which ended with: "Give me liberty or give me death." Few remember another speech in which he said: "Since the achievement of our independence, he is the greatest patriot who stops the most gullies." What would Patrick Henry say if he were living today and found out that about 50 per cent of our land is undergoing severe erosion?

In the previous chapters, you saw how important soil is for the growth of food and other materials. Poor soil lowers biologic production. When biologic production is low, everyone is affected, for prices of food and clothing go up. In addition, farm families are made poor by impoverished soil (Fig. 225). All over our country, and the world, conservation of soil is a major aim. Conservation doesn't mean that we should not use the soil; it means rather that we should use it intelligently. It means doing those things which maintain soil fertility at a high level of biologic production.

To play your part in this vital job of conserving soil, you will need to understand three things:

1. What soil is.
2. How soil is lost (eroded).
3. How soil is conserved and improved.

STRUCTURE OF SOIL

Go out to your garden or to the woods. Scoop out about two pounds or so of topsoil, the top layer of soil in which most plants grow. Topsoil varies greatly in depth. It may extend several feet down or may be only one or two inches deep.

EXPERIMENTS IN SOIL STRUCTURE

Divide your two pounds of topsoil into two equal halves. Put one half of this soil into a two-quart glass jar. Then add water about two inches over the soil line (Fig. 226). You will see air bubbles leaving the soil. Was there this amount of air in the soil when it was in the ground? Probably some air was added when you transferred the soil to the jar. Soil under water (drowned soil) contains little air and most plants do not grow well in it. But all soil contains some air.

Now shake up the soil and water in the jar. Let the soil settle overnight. What do you find the next day? The soil particles have settled, the heaviest to the bottom, the smallest and lightest are at the top. At the bottom there may be sand or gravel, then silt (fine rock particles), then clay. At the top you may find floating bits of decaying plant material—bits of leaves or plant stems or roots. These bits of material are part of the humus (hū′mŭs) which consists of the decayed remains of dead plants or animals.

Almost all soils are made up of different parts of sand, clay, and humus. Soils which contain mainly clay are packed hard when they are dry and are doughy when they are wet. Soils which contain mainly sand are blown by the wind and do not hold water. Swampland which contains too much humus is mucky when wet and spongy when dry.

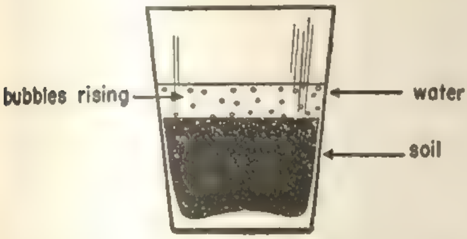
Good soil contains all three (clay, sand, humus) in good proportion. Such soil is called *loam*. In loam, there are enough large particles (sand and humus) to keep the soil porous and enough small particles (clay) to absorb water. The leaves, stems, and roots which make up most of the humus gradually decay and break down into fine, loose material. Humus contains minerals needed for plant growth, and encourages growth of soil bacteria, worms, and other soil organisms. Humus is extremely useful in holding water in the soil.

Freshly turned prairie land, or good forest topsoil, for instance, is a good type of loam. It has enough sand and clay to be worked readily by plow or shovel.

225 *An abandoned farm. The soil has blown away. How could this loss have been stopped? (Soil Conservation Service)*

EXPERIMENTS ON SOIL CONTENT

Now take the other pound of soil and pour out a quarter of a glassful. Put it in a covered metal pan and heat it over a flame. Look at the inside of the cover and you will note drops of water which



226 *According to this demonstration, what does soil contain?*

have been driven out of the soil. Without this water, the soil minerals would not dissolve. They could not be used by plants.

But what does soil water contain? Take a quarter of a glassful of the soil you collected and shake it up thoroughly for five minutes with an equal amount of distilled water. Now filter the soil and water. Put the filtered water into an evaporating dish and heat the dish till all the water is evaporated. You will find whitish mineral salts left behind. Definitely, soil water contains minerals. Some of the minerals which scientists find in soil are compounds of calcium, phosphorus, nitrogen, iron, sulfur, potassium, magnesium, sodium, manganese, and boron—to mention the more important ones.

It is these minerals which plants use in growth. Some of these minerals find their way into your body with your food and help build bones, teeth, and muscle. Examine Fig. 204. Notice what lack of certain minerals will do to plant growth.

Water and minerals are not the only things found in soil. You know that if you have ever dug for worms. With the worms, you may dig up insects, snails, pill bugs, and other animals. Some counts of the number of small animals have shown that there may be as many as 13,500,000 in an acre of topsoil. But these worms and other animals, especially earthworms, are a real help to man. They honeycomb the soil as they bore through it and make it easy for water and air to enter. They even bring little piles of soil to the top of the ground at night. Have you seen these worm castings? Earthworms get their food by swallowing soil and digesting part of it. When the soil material leaves their bodies, it is rich in nitrogen which all plants need for growth. Charles Darwin, a great English scientist, once observed that a stony field he had seen was completely covered with soil in some ten or more years by the action of the earthworms in it. Soil contains helpful animals.

In addition to the animals, scientists find in soil a good many microscopic plants such as bacteria and fungi. The richest soil has the most valuable kinds of bacteria. Some of these bacteria as you will see later on take nitrogen from the air and change it into substances which plants use for growth. Other bacteria attack and break down leaves and straw, thus increasing the supply of humus to the soil. The poorest soil has few or no bacteria.

PLAIN DIRT OR PAY DIRT

Gold miners still call dirt with gold in it "pay dirt." Perhaps you can see why we think soil isn't just plain dirt; it is "pay dirt." It is strong enough to hold the largest trees. Yet it contains air and water. It contains living things. It contains, most important of all, the minerals which living things need for

227 *The Willamette National Forest in Oregon. How does such a forest help conserve soil? (U.S. Forest Service)*

growth. Topsoil is more valuable to a nation than all the gold in the world.

DESTROYING SOIL

Our soil has taken centuries and even thousands of years to build up. The original rock has been broken down by wind, by water, by ice, and by thrusting tree roots. Plants have lived in it; their roots have remained. Animals have died and added their remains to it. Good soil is rich and life-giving. But it can be destroyed by ignorance and by carelessness.

LOSING SOIL BY LOSING ROOTS

When America was discovered, it is estimated that there were no more than half a million Indians living here. Today, there are close to 150,000,000 people. And in this growth much of our magnificent rich soil has been destroyed.

The early settlers had all the West before them. Prairie land was nearly free and unbelievably fertile. The pioneers cleared the trees from the forest and planted crops for a few years. Then they moved on to new land. So the damage began. For in plowing the soil the pioneers removed the trees and plant roots which held the soil. The tilled soil was left open to the rains which washed it away.

See for yourself how roots bind the soil. Take a thriving geranium plant and loosen it from the soil by sliding a knife between the pot and the soil. Now lift it out. Notice how the roots hold the soil.

There were some 822,000,000 acres of forests in the time of the Pilgrims. This was virgin forest containing the original uncut growth of trees. Wave

228 *The end result of careless lumbering. Notice the gully to the right. What should have been done to prevent soil erosion and to conserve timber?* (*U.S. Forest Service*)

upon wave of settlers cut down the trees. As the frontier pushed ever westward, timber was wastefully cut. No provision was made to spare young trees to take the place of the felled giants.

A few figures will help you understand the problems. In 1909, it was estimated that the total supply of saw timber in the United States was 2,826,000,000,000 board feet. By board feet is meant the number of feet of usable boards of a certain size cut from trees which can furnish boards (saw timber). In 1945, the estimate was that we had 1,601,000,000,000 board feet. You can see that the nation's woodpile had been reduced by 44 per cent since 1909. This means that our forests have been cut down to a dangerous point. The Forest Service estimates that we are not growing our saw timber fast enough to replace that which is being cut. Furthermore, the forests in the East have practically disappeared; 96 per cent of the virgin timber left in the United States is in the Western states (Fig. 227).

Although our present practices in cutting lumber are much improved, in earlier years the trees whose leaves broke the force of falling rain often were cut (Fig. 228). The unchecked rain removed the humus which once soaked up the rain water. The rain then washed away topsoil no longer held by living roots. Then the heavy clay beneath the topsoil washed into the valleys, where it covered the topsoil. Worse than that, the rain tore gullies in the hillside and washed the soil into our rivers. Then the rivers grew dark with the wasted wealth of the nation.

DEPLETING SOIL OF ITS MINERALS

Soil without its minerals is useless for plant growth. As you remember, plants use large amounts of nitrogen, phosphorus, potassium, and calcium for growth, in addition to small amounts of iron and other substances. But if crops are planted regularly without returning these minerals to the soil, essentials to plant growth are soon removed. The soil is then said to be depleted.

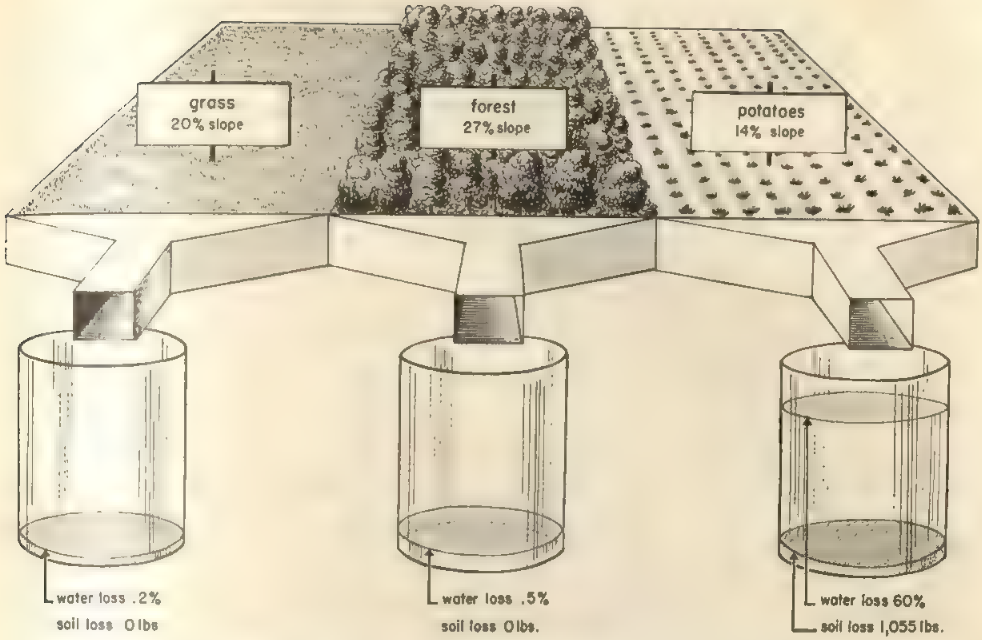
Examine the figures below for yourself. They tell us a story of the depletion of minerals from crop lands and pasture lands in 1934.

The conclusion is plain. In 1934, we were taking from the soil more minerals than we were putting back. The story is little different today, despite some improvement.

Soil not bound by plant roots is at the mercy of winds which blow it about and make dust storms. When trees,

	Nitrogen (tons)	Phosphorus (tons)	Potassium (tons)	Calcium (tons)
Total losses	16,100,000	2,500,000	36,200,000	53,600,000
Total returned	11,830,000	1,100,000	4,800,000	13,800,000
Net losses	**4,270,000**	**1,400,000**	**31,400,000**	**39,800,000**

229 *A flood in a Southern city. How do forests help prevent floods?* (Acme)



230 *A diagram illustrating water erosion. In which case is the most soil and water lost? in which the least? (Notice the figures giving the slope of the land.)*

shrubs, and grasses are removed, the topsoil is not held together. This topsoil is carried by rains, which may swell rivers until they overrun their banks. Great floods come to the valleys of the Tennessee, the Mississippi, the Missouri, the Ohio, and the Susquehanna. These floods ruin surrounding property, destroy life, and spread soil over hundreds of thousands of acres (Fig. 229). The Mississippi alone carries 750,000,000 tons of soil into the Gulf of Mexico yearly. What can be done?

A FARMER TRIES TO SOLVE HIS PROBLEM

Let's see what a farmer whom we shall call Mr. D actually did for his soil. He hadn't always owned his farm. He worked hard and finally bought one with soil which showed depletion. Also the sloping fields were eroding. He said, "I know it's poor, but I think I know how to make it right again."

First, he knew that good soil has these characteristics:

1. It can hold enough water for growth.

2. It has all the minerals for good growth.

3. It has a topsoil which is stable; that is, it cannot be blown away or ravaged by floods.

Second, Mr. D knew of the experiments of the United States Soil Conservation Service. This Service gave him information like this:

1. An acre of land with a slight slope continuously planted with potatoes lost approximately 60 per cent of its rainfall. It also lost about 1,000 pounds of soil in 19 rainy days (Fig. 230).

2. An acre of land planted in grass lost only about .5 per cent of its water, but almost none of its soil (Fig. 230).

3. An acre of forest land lost about the same as land planted to grass and

practically none of its soil (Fig. 230).

Third, Farmer D got a great many facts about plant growth from the scientists of the laboratories of the United States Department of Agriculture.[1] For instance, these scientists had grown green plants in solutions of minerals. In some of these solutions, they added different amounts of certain substances like calcium or potassium. After many years of work they discovered how much of each substance is necessary for the best growth.

As a matter of fact, plants can be grown in water, provided the substances needed for plant growth are added. You can actually grow vegetables in your own living room at home! Tomatoes, corn, cabbages, potatoes, and other vegetables have been successfully grown without soil. However, at present, this method of growing plants is too expensive. It is still best to grow plants in soil which holds sufficient water and has enough minerals for good growth.

SAVING AND REPLENISHING SOIL

Farmer D first planted his eroded sloping fields in grass and clover, plants which bind and hold the soil. He used fields with bad slopes for pasture only —never for crops. He repaired the stone walls at the bottom of the slopes. These walls acted as brakes for any soil washed down the slopes. In addition, he planted trees around every field to help hold any soil which was washed down and to prevent winds from blowing the soil away.

[1] Many of these important facts are summarized in a book called *Soils and Man*. You can get this book by writing to your Congressman.

CHECKING EROSION IN DITCHES AND GULLIES

Once all his sloping fields were planted in grass and clover, Mr. D went to a meeting of his farm neighbors at the schoolhouse. He spoke earnestly and well. He said that soil erosion was a community problem and that the children ought to have a hand in solving it. By the end of the meeting he had gained the help of the school board. The special job of the school children was to stop erosion by working on the ditches and gullies.

First, the boys and girls of the community used loose rock to build dams in the small ditches and gullies. The water would be held by the dams and prevented from enlarging the gullies. Then they planted the big gullies and ditches with kudzu vine. This vine spreads rapidly and holds the soil. Since it belongs to the pea family it helps add nitrogen to the soil. Soon teams of boys and girls had placed dams in every big gully or ditch in the vicinity or planted kudzu vine where necessary.

CHECKING EROSION ON HILLSIDES

The previous owner of Mr. D's farm had used even the hillsides for crops. He did not know, or did not care, that steep hillsides are poor crop land. The rain water rushes down the unprotected slopes, digging up the topsoil and muddying the creeks at the bottom with it. Soon the hillside is a mass of exposed rock and gullies unable to support a crop (Fig. 231).

But the teams of boys and girls did not lose this hillside to the forces of erosion. They planted the slope with thousands of small evergreens—pines and hemlocks—to hold the water and bind the soil. The covering of needles which falls on the ground holds the water and the roots hold the soil.

CHECKING EROSION IN CROP LAND BY CONTOUR PLOWING

Meanwhile, Mr. D was plowing his ground. But what a difference! He did not plow up and down his mild slopes for the furrows from such planting would act as ditches down which rain would pour carrying soil with it. He plowed across the slopes curving his furrows or rows with the contour, or curving shape, of the slope (Fig. 232). This is called *contour plowing*. After contour plowing, each furrow and row acts as a dam to catch and hold the water.

CHECKING EROSION BY STRIP CROPPING

Mr. D decided to plant his mild slopes in strips 75 feet wide (Fig. 232). In one strip, he planted corn. In the next strip, he planted grass. He might have planted clover, oats, wheat, or soybeans, all of which are cover crops, covering the soil. Then in the next strip he planted more corn. In between strips of cover crops, he might have planted strips of potatoes or tobacco.

You see, corn, tobacco, or potatoes are generally cultivated clean; that is, all other plants (such as weeds) except the corn, tobacco, or potatoes are removed. "Clean cultivation" leaves the soil exposed to the rains. The soil is not covered by the leaves of plants which break the force of rainfall. But the other crops in the next strip (grass, clover, oats, or soybeans) are planted thick and are not cultivated clean. So the soil which may be washed down from the corn strip is caught by the next strip of thick-growing clover, grass, oats, or soybeans. In addition, the roots of the thickly planted grass and clover bind the soil so that it remains on the land. Planting the soil in strips is called *strip cropping*.

231 *The part of this hillside on the right has been planted in grass. The part on the left is unplanted. What conclusion do you draw?*

232 *Contour plowing and strip cropping help to reduce the loss of soil.* (Gendreau)

CHECKING EROSION BY CROP ROTATION

When a slope is plowed straight up and down and planted with corn or potatoes, as much as 1,000 pounds of soil may be lost in 20 days of rain. The loss from a steep slope is greater but 1,000 pounds of topsoil may be lost on even a 14 per cent slope wastefully plowed and planted.[1]

Even with contour plowing and strip cropping, a field planted in corn, potatoes, or tobacco year after year, might soon be ruined. So from one year to the next, Mr. D varied his crops; that is, on the strip where corn had been planted previously, he planted oats or wheat. On the same strip he planned to plant clover, grass, or soybeans the next year. Some strips he planted with a mixture of the clover or alfalfa and grass seed with oats. When he cut his oats, the grass and clover came up. In the following year, he would be able to plant corn again without damage to the soil.

The planting of corn one year, then oats or wheat the next year, then clover and grass the third year on one plot of ground is called crop rotation. Southern farmers are learning to rotate cotton and tobacco with peanuts and soybeans. You can see that crop rotation cuts down soil erosion. In addition, the clover adds nitrogen to the soil, thus cutting down soil depletion as well as erosion.

[1] A 14 per cent slope means a 14 foot drop per 100 feet.

REPLENISHING THE SOIL—PUTTING BACK NITROGEN

Stopping erosion is not enough. Growing and harvesting crops each year takes certain minerals from the soil. These minerals must be put back or the soil, even if it did not erode, would soon be worthless for producing food. The most important losses are the nitrogen compounds. They dissolve easily and so are carried away in the water running off the land. Then too, plants use nitrogen compounds in large quantities. One of the best ways to replenish the soil with nitrogen compounds is to plant clover, soybeans, or cowpeas—all plants of the same family called legumes.

Go out in the field or yard and pull out a clover plant. Examine the roots. You will see the small *nodules* (nŏd′ūlz) or swellings on the roots.

The nodules are full of bacteria. These bacteria are known to take nitrogen from the air and soil and make nitrogen compounds from it. When the crop is cut, the roots remain in the ground and the soil is enriched with the nitrogen compounds. Aside from replenishing the soil, the roots remaining in the ground help bind the soil.

REPLENISHING THE SOIL WITH FERTILIZERS

Good farmers do not rely on leguminous plants alone to replenish lost minerals and nitrogen compounds. Year after year, they add animal manure, which contains some of the minerals removed from the soil by the plants the animals ate. Farmers also add chemical fertilizers (phosphates, nitrates, and lime) which are supplied to farmers at special prices under a government plan. Some of the chemical fertilizers can be obtained free under the government plan to help farmers restore land fertility.

Slowly but surely Farmer D reduced the erosion on his land. Gradually, he increased the humus in the soil to hold the water. And with fertilizers he restored minerals taken out by his crops. Year after year his crops improved, and Mr. D proved to the farm community that poor land can be restored when the right methods are used.

TVA

Farmers who live in the Tennessee Valley sometimes talk about the time before the TVA. They talk of the way the uncontrolled Tennessee River and its tributaries carried away tons of fertile topsoil. The rampaging rivers made the land poor, and the poor land made the people poor.

However, the Tennessee Valley Authority came to the aid of the valley and its people. This TVA, as it became known, was one of the most important acts in the whole history of soil conservation. First, the TVA, which extends into five states, set about building dams to control the rivers (Fig. 233). Not only did these dams eliminate floods, but the water power from them also made cheap electricity available to all the farmers. This made farm work easier, and living more comfortable. While it was building dams, the TVA began a vast program of replanting forests to prevent floods. It set up classes and demonstrations of soil-preserving methods. Its factories manufactured large quantities of cheap fertilizers. Today the TVA continues as a source of strength in the national program of soil conservation.

CCC

If you were a farmer, would you have supported projects like the Civilian Conservation Corps (the CCC)? From 1933 to 1937 this Corps supplied jobs to more than two million young men. What did

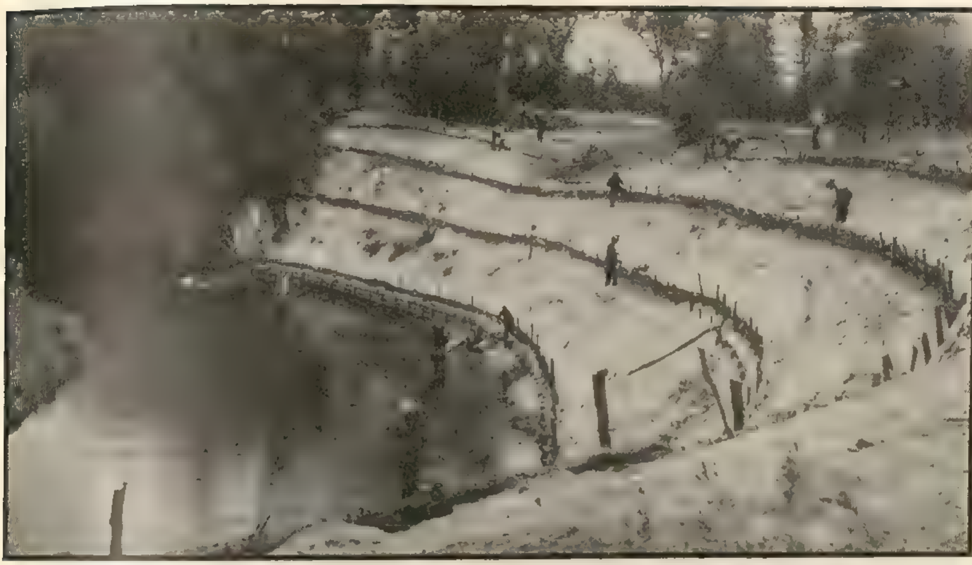
these men do? They planted about two billion trees and built about five million check dams on gullies. A check dam is a small dam built in a gully, or similar place, to check the loss of soil. They improved about three and a half million acres of forest land by thinning trees and destroying pests. They built about 100,000 miles of roads to help fight forest fires. They built about 6,000 small dams in rivers and creeks. Thus they helped check erosion. The CCC helped save soil. (Fig. 234).

ACTING TO CONSERVE SOIL

In 1935, the Congress of the United States passed the Soil Conservation Act and established the Soil Conservation Service, which now gives advice and help to all farmers. It encourages soil conservation by giving many prizes to farmers with the best soil conservation practices. It establishes model farms, where farmers from the surrounding countryside can see how erosion is checked, how soil is replenished and made productive.

The Soil Conservation Service also reclaims soil by planning irrigation projects. Even desert land has been reclaimed. Water from dammed-up reservoirs flows into irrigation ditches. The water dissolves the minerals. The minerals diffuse into the roots of the plants. Desert land becomes useful—and people can live on it.

233 *Norris Dam in Tennessee, the first TVA dam project to be completed. How do dams help stop loss of soil?*



234 *Bank erosion control in Michigan. How do these fences stop the loss of soil?* (*U.S. Forest Service*)

MR. D IS AN EXAMPLE

Now if Mr. D's methods were applied on every farm in this country, the 61 per cent of our crop land which is turning from bad to worse would be much improved. We would not see the chain reaction from poor soil to poor farms to poor people to poor nation.

There is much evidence that people everywhere have learned the lesson of conservation of our forests. The United States Forest Service reports that although we have far to go, we have begun to recognize the problem and are beginning to take steps to solve it. The majority of owners of large timberlands are doing a fair or better job of managing their forests. But they hold only 15 per cent of the timberlands. The other 85 per cent is held by small owners; 40 per cent of our timber is on farm land. These small owners are learning to use their woodlands intelligently. As trees grow to maturity, they are cut down to make room for younger trees. Excess growth is removed to permit circulation of air and to let sunlight enter.

Throughout the nation, soil conservation programs are being carried out by farmers everywhere. Men trained in the intelligent use of soil, who know how to get the most out of it without wasting it are leading the fight against soil erosion. These men are the county agents, men in the government service, who help the farmer conserve his soil—that is, use it wisely. America, in short, has become conservation conscious and is saving soil, its source of wealth.

GOING FURTHER

1 *Analyzing soil.* Get three samples of soil: rich humus, ordinary garden soil, and a loam soil.

1. Burn a thimbleful of each in a porcelain dish. An ammonia-like odor indicates the presence of nitrogen. Which soil has most nitrogen compounds?

2. Shake up a thimbleful of each kind of soil with water. Examine a drop or so under the microscope. Which soil has

the most living organisms? Draw some of these.

3. Repeat the experiment on page 335 which determines whether soil contains minerals. Plan an experiment to determine the amount of mineral substances in each kind of soil. (Hint: Use equal amounts of dry soil by weight.)

2 *Acid and neutral soil.* Take four equal-sized pots of soil. Add lemon juice (which contains citric acid) to the soil in all pots until the water dripping from the potholes is acid to litmus paper (blue litmus turns red in acid). Now mix enough agricultural lime (limestone) into the soil of two pots to turn the litmus neutral. Plant corn seeds in one pot with acid soil, and in one with neutral soil. Plant beans in the other two. Allow them to grow in a sunny spot. Keep careful notes. What are your conclusions?

3 *Soil minutemen.* If you live in a farm area, take a field trip to survey good and bad farm practices. Organize a club of "Soil Minutemen" to help fight erosion.

4 *A model farm.* Make a model of a farm with good farm practices. You can use bits of sponge colored green for trees in forests, pebbles glued on cardboard for stone walls. Your teacher will give you more help if you need it.

5 *Words are ideas.* Can you use these words in a sentence which will give their meaning? Use the glossary.

erosion	humus	crop rotation
wind erosion	loam	fertilizer
water erosion	topsoil	TVA
contour plowing	terraces	CCC
check dam	mineral	strip cropping

6 *Put on your thinking cap.* Out in the Missouri Valley, farmers are discussing the value of building dams and controlling rivers. Some are against it. They say it costs too much and doesn't do much for the soil. Some are for it; they say it will save money in the long run, increase the productivity of the soil. What evidence could you give on either side?

7 *Test yourself.* In your notebook match the letter of the item in the right column with the number of the item to which it is related in the left column. Do not mark this book.

1. the upper 18 or 20 inches of tillable soil	A. clay
2. a plant that can put nitrogen into the soil	B. humus
3. an animal which helps aerate soil	C. legume
4. soil composed of the very finest of soil particles	D. nitrate
5. remains of decayed plant and animal matter	E. nitrogen
6. a gas that occurs in air (needed by plants)	F. nodules
7. a method of decreasing the loss of soil on a hillside	G. earthworm
8. process by which soil loses minerals	H. contour plowing
9. a compound containing nitrogen needed by plants	I. topsoil
10. structures on roots of leguminous plants	J. soil depletion

8 *Adding to your library.* You will surely want these pamphlets. Write to the Superintendent of Documents, Washington, D.C., for the following:

1. *Little Waters* by N. S. Persons (15 cents). An admirable little booklet on soil conservation.

2. *Soil Defense in the Piedmont,* United States Department of Agriculture, Farmers Bulletin No. 1767 (15 cents). The story of a fight to save soil in the south.

3. *To Mold the Soil,* United States Department of Agriculture, Miscellaneous publication No. 321 (45 cents). If you have been impressed by the warning in this chapter you will find this booklet even more impressive—and very important.

4. You should also write to your Congressman for three books—*Soils and Men, Farmers in a Changing World,* and *Science in Farming.* Each book is about 1,200 pages. They are very valuable reference books on soils and farming.

5. Find out all you can about the organization known as Friends of the Land which has branches in nearly every state of the union.

CHAPTER 20

USING FIELD AND FOREST WISELY

Let us look at some spots where our government's program of conservation is at work. Let us, for instance, watch the salmon run in the Columbia River. At the same time every year, salmon come in from the ocean and start up this river. Nothing stops them. They jump small falls. If they fail at the first try, they jump again and again till they gain the quiet waters above. Here and there where the falls are too steep, as in large dams, the men of the conservation service have built "fish ladders." These are a series of stone steps covered with water so that the fish can jump from one to the other to the top (Fig. 235).

Finally, the fish stop their migration to spawn in the upper tributaries of the river; that is, the females lay their eggs and the males deposit sperm over them. Soon the young of the salmon are hatched (Fig. 236).

After spawning, the adult salmon die. What happens to the young? They grow for a while and then they start on a long hard journey. Just as their parents came up the long difficult river, the young begin the long swim down to the ocean. Thousands of them start the journey; many die. In the ocean, they grow to adults. When they are adults ready to spawn, they start the long difficult swim to the exact place where they were hatched.

Year after year the salmon do this. Year after year the conservation department puts limits on the number of salmon that fishermen and commercial fisheries may take. Thus while great numbers of salmon are canned for food, enough go through to spawn so that the salmon are not wiped out.

When the Grand Coulee Dam was built on the Columbia River, scientists of the conservation service knew that the fish could never pass the dam on their journey up river. So began a great conservation experiment.

In the year when the building of the Grand Coulee began, scientists caught thousands of females and shipped them to hatcheries. There the eggs of the females were removed. The milt of the male, which contains the sperms, was mixed with these eggs. In other words, the eggs were artificially fertilized. As soon as the young hatched, they were placed below the Grand Coulee in the rivers which feed the Columbia River.

235 *A fish ladder at Bonneville Dam. These ladders make it easy for salmon to return to their spawning grounds.* (*U.S. Fish and Wildlife Service*)

Many of these fish were clipped through the tail so they could be recognized. Then they were allowed to swim out to the sea. One thing was certain: the adults would come back to spawn.

Now let us join a group of anxious scientists on the bridge below Grand Coulee when the fish were due to return from the ocean to spawn. Would the fish come up river and dash themselves to death against the torrents of water coming from the Grand Coulee? Or would they turn up to the new spawning grounds below the big dam? You will remember that this is where the young artificially hatched salmon were allowed to develop.

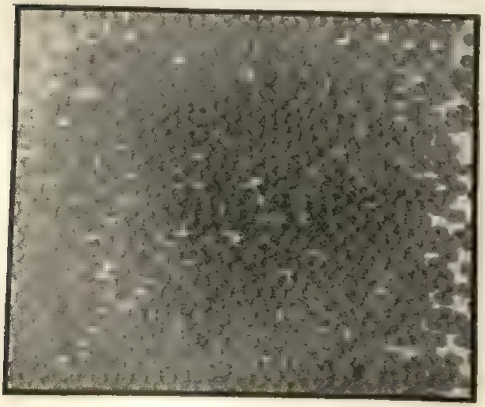
Tensely the scientists watch. Sure enough, here are the fish with clipped fins. They are not killing themselves on the rocks of Grand Coulee. They stop at the streams below in the exact place where they were first placed by the scientists. A quarter of a billion dollar industry and a valuable food supply has been saved by conservation.

THE PROBLEM IN CONSERVATION

Once there were great herds of bison (or buffalo, as they are so commonly called). Now there are very few bison, and all are fed and protected by the government. With protection these herds are growing to a size which can be fed and cared for on our present grazing grounds.

Once we had huge forests. But because of careless cutting and damage from insects, disease, and fire, they are much smaller now. True, about one-third of our land is still forest land. If

236 *The eggs of salmon* (left). *Salmon fry* (right). *Where will the salmon eventually develop into adults?* (*Both, U.S. Fish and Wildlife Service*)



this forest land is used wisely to keep it growing good trees continuously, it is enough to supply us with all of our needs (Fig. 237). It will supply forest products, protect much of our water supply, provide homes and food for wildlife, and give us opportunities for recreation which come only in the forest. But only about one-fourth of that forest land is used wisely now. From

237 *Logs for the sawmill. Why are good cutting practices necessary if we are to conserve our forests? (American Forest Products Industries)*

the other three-fourths, each year we are taking 50 per cent more timber than is replaced by growth. We still have about 200,000 forest fires each year which destroy about 30,000,000 acres of forest.

On our private forest lands, from which come most of our forest products, 64 per cent of the cutting is still poor or destructive, while only 8 per cent of it is good. Our tree planting program is not yet going at the speed needed to reforest the 75,000,000 acres of commercial forest land which must be planted if they are ever again to produce good timber. In spite of all of our advances in forest conservation, and there are many, these conditions still exist.

We need to do two things if we are to conserve our natural resources. We must first safeguard them against destruction by man, pests, and fire; second, we must give the plants and animals we want to conserve the best environment for continuous growth.

DESTROYING PESTS

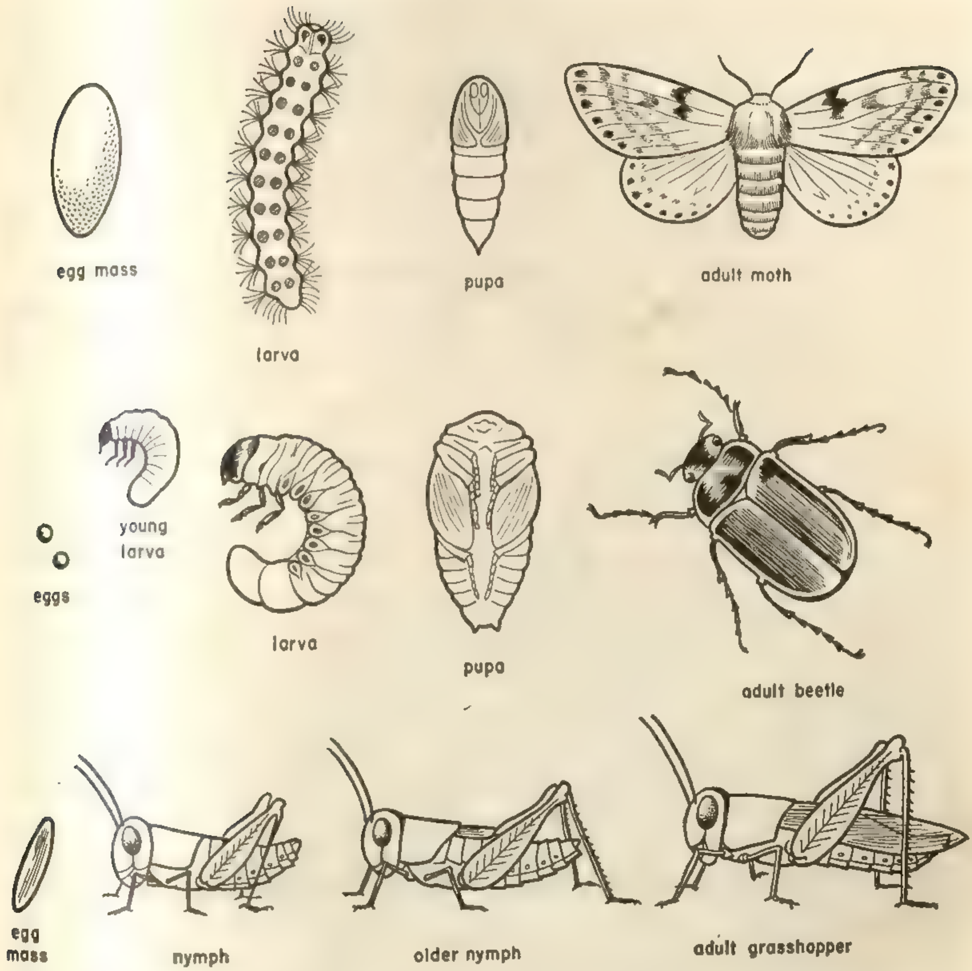
It is common knowledge that many insects are useful. For example, each year the bee produces a honey crop worth $75,000,000 in the United States alone. It also helps to cross-pollinate our fruit trees. Most insects that feed on flowers also aid in cross-pollination. The silkworm, the larva of a moth, produces some 120,000,000 pounds of silk per year. Some insects, like the lac insect, produce a dye. Still other insects, like the ladybird beetle, feed on plant lice and other destructive insects.

Many insects are pests, however. They destroy at least 10 per cent of our crops each year. The Colorado potato beetle may cause serious damage to the potato crop. The corn worm can ruin a farmer's corn crop. The Mediterranean fruit fly almost destroyed the Florida fruit industry before this pest was wiped out. In Table VIII is a list of some of our major insect enemies and their deeds.

Table VIII. SOME INSECT ENEMIES

The pest	Destructive work	General control
Codling-moth larva	Feeds on apples	Poison spray
Corn earworm	Feeds on corn	Crop rotation, poison spray
Cotton boll weevil	Larvae feed on cotton pods, called bolls	Spraying
Western grasshopper	Feeds on all grasses	Chemical spraying, fire (when large numbers infest the fields)
Gypsy moth	Feeds on all trees (New England)	Poison spray, banding of trees
Potato bug	Feeds on potato vines	Sprays
Chinch bug	Feeds on corn	Sprays
Japanese beetle	Feeds on wide variety of plants	Sprays
Cottony-cushion scale	Sucks juice of citrus fruits	Ladybird beetle
Flies, mosquitoes	Annoy livestock; carry disease	DDT*

* Spray carefully, follow instructions, and do not breathe in spray which is thought to be harmful to man and livestock.



238 *How do the life cycles of the moth and beetle differ from that of the grasshopper?*

In order to destroy insect pests, we must know their life histories. Once we understand their feeding habits and how they reproduce, we know how to check them before they reproduce in large numbers.

INSECT LIFE HISTORIES

The small white cabbage butterfly is an interesting insect to study (Fig. 238). It is present wherever cabbages are grown. If you watched one, you would see it lay its eggs on a cabbage leaf. In a week or so, each egg hatches into a tiny green wormlike animal, a *larva* (lär′vȧ). These larvae eat and eat cabbage till they become an inch long. Then they form a *pupa* (pū′pȧ) and undergo certain changes which make them into adult butterflies.

This life cycle consisting of four stages — egg, larva, pupa, and adult — is found in insects like the butterflies, moths, beetles, bees, ants, and flies. Next time you see a beautifully colored caterpillar you will know it is a larva of a moth or butterfly (Fig. 238). On the other hand, most larvae of beetles

are not colored like the caterpillars. They are usually tan or white (Fig. 238).

However, the pupa stage of some of these insects may be different. The pupa of insects is the stage wherein the larva undergoes changes and becomes the adult. There is generally no outward movement of the insect when it is in the pupa stage. Many moths spin cocoons in which the pupae are protected. However, most insects do not spin cocoons.

The larva of a butterfly or beetle is so different from the adult that it is hard for people to believe that one comes from the other. However, in insects like the grasshopper and its relatives (katydids, crickets, and roaches) it is easy to recognize the young. They look like the adults except that they do not have wings. Such young which resemble the adult insects (except for wings) are called *nymphs* (nĭmfs).

Grasshopper nymphs hatch from eggs which are laid in the ground in the previous season. Soon they develop wings and become adults.

TWO KINDS OF POISON

To poison the insects which rob us of our food and destroy our work, we must get the poison into their bodies. You will probably be surprised that some sucking insects can eat plants sprayed with poison because the poison never reaches their stomachs. Sucking insects like the aphids pierce the outer parts of the plant. Thus the tubelike mouth parts are thrust past the poison which is sprayed on the outside. The poison, therefore, does not get into the insect's body.

Biting insects, on the other hand, are quickly killed by poisons sprayed on the plants. Biting insects eat the outer portion of the plant. Therefore for this type of insect Paris green, lead arsenate, derris, or DDT may be carefully sprayed or dusted on the plant. It is best to dust in the morning when the leaves are wet. Large areas may be dusted by airplane.

For sucking insects, a different kind of poison called a contact poison may be sprayed on the insects themselves. Tobacco juice or nicotine sulfate (sometimes sold as Black Leaf 40) may be used. Or a mixture of kerosene and soap is helpful. It works this way.

All insects breathe by means of openings in the body called spiracles (spī′rȧ k'ls). These connect with a great number of air tubes which run to every part of the body. Most household insect sprays get into the insect's body through the spiracles. They are breathed in, so to speak. Some contact poisons close up these spiracles and the insect dies because of lack of air. On the other hand, some poisons like DDT (Table VIII) enter the body and poison the nervous system of the insect.

A poison like rotenone (rō′tē nōn) or DDT can be used to kill sucking and biting insects as well. DDT will also kill insects which happen to walk or rest on traces of it. It is important to follow directions in spraying DDT. Some authorities believe that if the poison is not used carefully, it may result in harm to human beings. Furthermore, if DDT is not used carefully, it may kill valuable insects such as bees. As you may know, the farmer depends on bees to cross-pollinate his fruit trees and to supply honey.

PROTECTING FARM ANIMALS AGAINST PESTS

Just as the farmer protects his plants, so he protects his animals. He sprays his barns and chicken coops with DDT to kill insects which live in such places. He screens his animal houses to keep

the insects out. He dusts his poultry with insect-killing powders to get rid of bird lice. He sprays or dips his cattle and sheep in creosote to get rid of ticks, mites, and lice (Fig. 239).

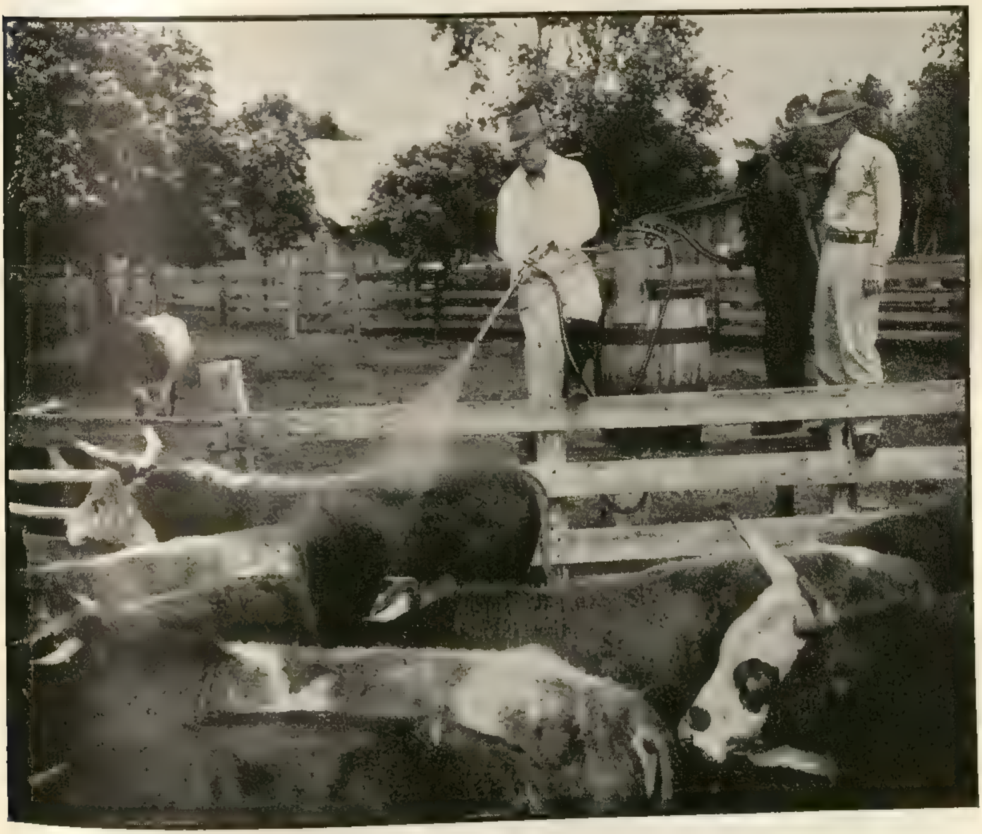
BIRDS ARE THE FARMER'S ALLIES AGAINST PESTS

The contents of a bird's stomach would show you how birds serve the farmer. They eat the insects which feed on the farmer's crops. Here is what scientists discovered by examining the contents of birds' stomachs.

One yellow-billed cuckoo had about 275 caterpillars in its stomach; a starling had eaten some 3,000 assorted insects. A killdeer had 300 mosquito larvae, while a single nighthawk had destroyed 340 grasshoppers, 52 bugs, 3 beetles, 2 wasps, and 1 spider. Other birds had a different diet. A ring-necked pheasant had eaten about 8,000 chickweed seeds; a mourning dove had gathered 700 seeds of various weeds.

The robin is another of the farmer's aides. Of course, robins may eat a few cherries. But scientists have shown that the robin's chief diet is worms, grasshoppers, beetles, bugs (like the chinch bug), and wild fruits, like wild cherry, huckleberry, and elderberry. The chickadee in summer and winter eats tremendous numbers of insects.

Birds should be encouraged to reproduce and they should be protected



239 *Cattle being sprayed with DDT. What is being controlled by means of the spray? (U.S. Department of Agriculture, Bureau of Entomology and Plant Quarantine)*

240 (Left) *Close-up of a Japanese beetle.* (Right) *Japanese beetles at their destructive work on a peach.* (*Both, U.S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*)

against hunters, cats, and starvation. Do you have winter feeding stations with suet and bird seed? Do you have a place where the birds can get water? If you do, your garden may be freer from insects and weeds than it ever has been before.

On the farm, a few protected places will give birds a place to breed. Sparrows, swallows, orioles, bobolinks, finches, kingbirds and other flycatchers, bluebirds, robins, wrens, brown thrashers, and quail are all the farmer's friends. They should be treated as friends.

MEN AGAINST THE MEDITERRANEAN FRUIT FLY

In the spring of 1929, Florida was invaded by one of the worst of all citrus fruit pests, the Mediterranean fruit fly. Congress voted more than seven million dollars to fight this invasion. About 120,000 acres of orchard land were infested; more than 1,000 separate orchards were involved. If these pests were allowed to live, all of the oranges, tangerines, and grapefruit of Florida and its neighboring states would be damaged. This is what was done.

1. All fruit trees were sprayed with poison.

2. All fruits on the infested properties were destroyed.

3. All states to which fruit had already been shipped, were warned.

4. No fruit could leave Florida; the state was under quarantine.

The result: The Mediterranean fruit fly, a very dangerous pest, was put under control in about a year.

MAN AGAINST A BEETLE

A grim fight is now being waged against the Japanese beetle (Fig. 240), which in 1916 was brought accidentally to New York City from Japan. These

beetles are now moving westward and they eat many sorts of plants—corn, oak leaves, roses, fruit (Fig. 240). How can we delay their spread?

The English sparrows eat a good many Japanese beetles, but not enough. However, scientists have found that the larva, or grub of the Japanese beetle has a contagious disease which spreads from grub to grub and kills many of them. This milky disease (as it is called because the beetle grubs turn milky white) is therefore being spread in areas infested with this pest.

The natural enemies of the Japanese beetle have been imported from Japan. One of these is a wasp whose young feed on the grubs of the beetle. Many thousands of wasps have been bred by the Department of Agriculture and released into the fields to kill the beetle.

How are Japanese beetles being fought in your area? If you have never seen one, it is because the work of scientists has destroyed them or delayed their progress to your area. So the fight goes on—day in, day out. Man must win the fight. How?

1. By poison spray (stomach or contact poison).
2. By encouraging the enemies of insects (birds and other insects).
3. By spreading diseases of insects.
4. By rigid plant inspection.
5. By breeding plants resistant to insects.
6. By destruction of susceptible plants.
7. By quarantining affected areas.
8. By rotation of crops.
9. By destroying breeding places.

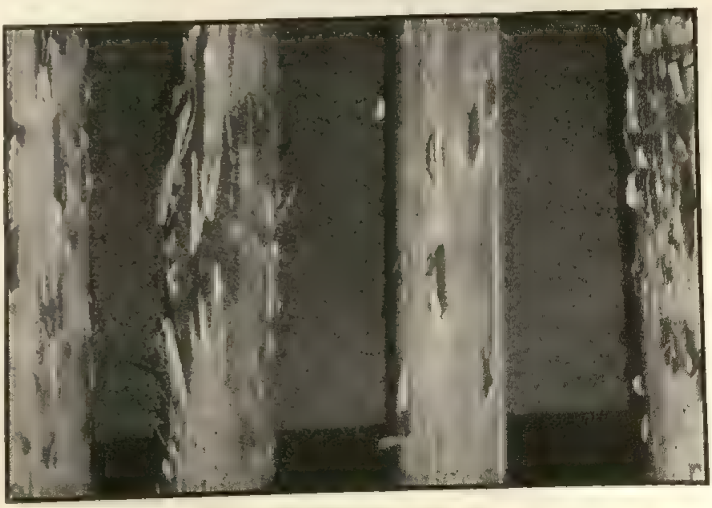
FUNGUS PESTS

Have you ever seen an ear of corn or a stalk of wheat stained by a black powdery material (Fig. 241)? If you examine some of this powder under the microscope, you find that it is made up of thousands of *spores*. Spores, you remember, are the tiny reproductive cells of fungi.

MAN AGAINST FUNGUS PESTS

Fungi are simple plants that lack chlorophyll. Since they don't have chlorophyll, they cannot make their own food. They must, therefore, get their food from other plants, animals, or nonliving matter.

The black spores on oats or corn are produced by fungi called smut fungi



241
Wheat badly damaged by a rust. The second stalk from the left is especially hard hit. (U.S. Department of Agriculture, Bureau of Entomology and Plant Quarantine)

that cause great damage to our grains. Some smuts can be controlled by treating the seeds before planting. But corn smut cannot be controlled in this way since the smut fungus infects the growing plants. One way to control these fungi is to breed corn, wheat, oats, barley, rye, and other plants that are resistant to smut disease.

The rust fungi that are very similar to the smuts cause even more damage. Control of some of these rusts has come from learning their life cycles, that is, their life histories. It has been discovered that wheat rust and some other rusts have two hosts.

A *host* is the plant or animal on which the fungus grows. One host of the black stem rust is, of course, wheat. However, one part of the rust's life cycle is spent on a second host, the native barberry. On the leaves of this plant, the rust fungus produces tiny bright rust-colored caps that are full of spores. There is no good substitute in the life of the wheat rust for barberry. Remove the barberry and you destroy the rust. Since 1918, the government has been killing off native barberry bushes, especially in the valley of the Mississippi. Where the second host is destroyed, the fungus cannot propagate itself. Losses from wheat black stem rust already have been lowered by nearly half.

The cedar is one of the hosts for the apple rust. Can you see why cedars should not be planted within 10 miles of an apple orchard? Here again the best protection against rusts is to breed resistant plants.

MOLDS AND MILDEWS

You have probably seen molds. A common one is the bread mold. Let us produce a bread mold. Expose a piece of bread to the air for about ten minutes. Now place it in a closed jar in a warm place. Add a few drops of water. In a few days, you will see a fuzziness; in a week, the bread mold will be producing spores in small black pinhead-like bodies. These spores are carried by the wind and will grow on moist bread or grains.

Since moisture is necessary for the growth of molds, storage places for grains should be dry and bread should not be kept in a moist place.

Mildew spores, too, are found almost everywhere. They are fungi that will grow on plants, leather, and clothing—any place where there is sufficient moisture, warmth, and food.

PREVENTING GROWTH OF FUNGI

You can see that molds and mildews need (1) food, (2) the right temperatures, (3) moisture, and (4) oxygen. We have learned how to prevent the growth of those fungi by preserving our foods. We take the water out of foods (dehydrate them). This denies moisture to the fungi. We freeze foods or refrigerate them and thus deprive the fungi of the proper temperature for growth. By canning food, we deny fungi oxygen. We also kill them by heating our food to a high temperature. Scientists have even developed ultraviolet lamps that help kill mold spores.

The spores of fungi are everywhere. We must always be on guard against them.

CONSERVING WILDLIFE

In this unit, we have discussed ways of conserving our food plants and animals by destroying the pests that feed on them, harm them, or kill them. We have described conservation on the farm as a problem of maintaining con-

ditions that assure the greatest reproduction of our food, both animal and plant. Conservation on the farm also means protecting the soil. This is so important that the whole of Chapter 19 was set aside for this vital topic.

LENDING A HELPING HAND

Conservation in the field and forest means protecting and lending a helping hand to the wildlife, the trees, and other plant life so that they may at least hold their own.

Wildlife, plant or animal, gives us food as well as pleasure. Fishing and hunting still provide food for many people. But apart from food, suppose there were no woods for hiking? Suppose there were no lakes and streams for vacations?

Our conservation program does at least six things.

1. It protects our forests from insects and diseases. It fights forest fires and replants those forests which have been destroyed.
2. It limits the killing of wildlife.
3. It establishes refuges for animals in danger of being exterminated.
4. It restocks streams and lakes with fish.
5. It seeks to get the public to realize the importance of conservation.
6. It fights pollution of streams and lakes.

LIMITING THE CATCH AND BAG

Throughout the United States, the catch of fish is limited. Not only is there a fishing season, but the number of fish caught at one time is limited and fish under a certain size must be put back and allowed to develop.

Our conservation program also limits the bag of wild birds and game; huntsmen are allowed only a certain number of deer, ducks, birds, and other game during the hunting season. During the rest of the year the game is allowed to reproduce, replacing the animals that have been killed.

NO LIMITS TO THE CATCH AND BAG ON ENEMIES

Just as the catch or bag is limited for certain animals so there is no limit on others. For instance, in many states there is no limit in the hunting season on rabbits. The rabbits reproduce so fast that they may actually eat up vegetable crops, or they may destroy trees by gnawing at the bark. Hunting keeps the number down.

In Australia, rabbits were introduced by man. This was a mistake. There the rabbits had no natural enemies like the coyotes, hawks, and foxes that prey upon them in the United States. The rabbits reproduced in such great numbers that they made farming impossible in many places. They dug under fences, ruined crops, and ate the bark from fruit trees. Now there is a bounty in Australia for every rabbit killed. The Australians, however, are still having difficulty in keeping the number down.

A PRINCIPLE IN CONSERVATION

Scientists have found, as you have read, that animals and plants live in a balance. Introducing a new animal may destroy this balance so that one animal may reproduce in very great numbers. This points to an important principle in conservation. The conservation service protects only those animals and plants that need protection. For instance, in some states, it is against the law to hunt quail. These valuable insect-eating birds need protection because they can just about keep their numbers up at the same level each year. However, in the same states, there is free rabbit hunting all season because

242 *Mountain laurel. It is unlawful to pick this plant. Why? (American Museum of Natural History)*

the rabbits are a danger to the crops in that area. In some states the coyote population is too high, and hunters are hired to kill them.

When certain wild flowers like orchids, dogwood, and mountain laurel (Fig. 242) have been picked too freely, state laws have been passed making it illegal to pick them. Under this protection, these plants are beginning to reproduce more widely. The principle is: Protect the wildlife whose numbers are decreasing rapidly and reduce the number of those that damage crops or other animals.

Under this principle, none of our animals or plants need ever suffer extinction.

REFUGES AND SANCTUARIES

For those animals whose numbers are decreasing too rapidly, wildlife refuges are set aside. Here the birds and beasts are safe from hunters. If we could take you on an airplane trip of our wildlife refuges over the nation, here are a few of the things you might see.

You would see bison feeding and thriving in the National Bison Range in Montana (Fig. 67).

You would see the trumpeter swan flying majestically over the Red Rock Lakes National Wildlife Refuge in Montana. This bird was very near extinction before it was protected by law and refuge (Fig. 243).

You would thrill to the sight of snow geese rising from the cattails in the Sacramento National Wildlife Refuge in California (Fig. 244).

Flocks of Canada geese would honk their greeting from Bear River Migratory Bird Refuge in Utah.

Antelope would look up at you from their water holes on Sheldon Antelope Refuge in Nevada (Fig. 245).

Deer might also stop and look at you from the refuge of the National Bison Range in Montana (Fig. 246).

You know that many birds migrate, some from country to country. For instance, geese may breed in Canada and migrate to the United States. Many of our insect-eating birds do this regularly. You will be glad to hear that there are Migratory Bird Treaties made by England, Canada, Mexico, and the United States to protect birds like the egret, trumpeter swan, and others against destruction in any of these countries.

SAFEGUARDING FORESTS

People who understand that killing an animal is not always a good thing, do not always feel the same way about killing plants. Plants cannot move and

243

A trumpeter swan on its nest in Red Rock Lakes National Wildlife Refuge, Montana. (U.S. Fish and Wildlife Service)

244

Lesser snow geese, white-fronted geese, and cackling geese rising from Heart-shaped Lake, Sacramento Refuge, California. (U.S. Fish and Wildlife Service)

245

Antelope on the Charles Sheldon Antelope Refuge, Nevada. (U.S. Fish and Wildlife Service)

246

Young whitetail deer (buck) with budding antlers, in the National Bison Range, Montana. (U.S. Fish and Wildlife Service)

do not make sounds. Nevertheless, a tree takes a long time to grow. The Sequoia trees (or giant redwoods, as they are called) are thousands of years old. A good forest may quickly become a poor forest if young trees are not permitted to grow to maturity.

The United States Forest Service estimates that there are, on the average, about 200,000 forest fires a year, or 548 a day. They damage about 7 per cent of our total forest area annually (Fig. 247). In 1894, the great Hinckley fire in Minnesota destroyed timber worth $25,000,000, killed 418 people, and leveled 12 towns. In Pennsylvania, nearly two million acres of forest land have been practically destroyed by fires which have swept the area again and again. In 1947, Maine forest fires destroyed several towns and resulted in $30,000,000 damage. The forests which once grew giant white pines are now mostly scrub oaks and aspens.

Who is responsible for these fires? Usually man. Careless smokers, unextinguished campfires, a lighted match thrown thoughtlessly aside, may be responsible for a fire like the Tillamook forest fire in Oregon. In 1933, this fire burned some 267,000 acres—a loss of $350,000,000 to labor, industry, and the public.

In addition to forest fires, insects take a tremendous toll of the trees. The Engelmann spruce beetle in the Rocky Mountains destroyed a 1,600 square-mile stand of spruce from 1939 to 1948. In this one outbreak, enough timber was killed to build 450,000 five-room houses. The gypsy moth and browntail moth still do considerable damage to trees in the New England region.

PREVENTING AND FIGHTING FIRES

Our forests are safeguarded by the trained men of the United States Forest Service. Foresters and rangers are employed by industry and by many state conservation commissions (Fig. 248). Read what the Michigan State Conservation Commission does for its forests and trees. More than 7,808,000 acres of state and private land, as well as National forests, are watched carefully for forest fires. Fire towers are manned day and night by trained fire watchers. Forest guards patrol constantly. Trained fire crews are on constant call to answer any alarm. Since this plan was put into practice, the number of forest fires has gone down considerably. In 1947, only .15 of 1 per cent of the protected area was burned although there were 1743 distinct forest fires.

In addition, about 870,000 acres have been planted with trees provided at cost by state tree nurseries. As windbreaks on farms, these trees will save crops. As wood lots, these trees will hold water and build up soil. The decayed leaves and underbrush will soak up water and the green leaves will soften the fall of rain. The roots will help hold the soil. The streams will run clear, not muddy. In a few years, some of these trees can be cut for pulpwood, saw logs, fence posts, and firewood.

Are you a farm boy or girl? Do you have a windbreak or wood lot on the farm? Write to your state forester for information on how to get trees for planting.

Are you a city boy or girl? Next time you go on a hike will you build your cooking fire carefully?

These forests are yours. By saving soil and water, they bring you better food, and more food. They also bring beauty and rest. Walk through them, camp in them, play in them, but do not destroy them. Let us use our remaining forests carefully.

247 *A forest fire such as this one destroys valuable trees, property, and lives. What is your part in the prevention of forest fires? (Western Pine Association)*

248 *Respect this sign. Why is it to your advantage to do so? (American Forest Products Industries)*

BALANCE IN A FOREST SANCTUARY

Come with us to the Audubon Wildlife Sanctuary, named after one of our great early naturalists. Sit down here in the shade of a big tree and watch. There is a rustle in the underbrush. A big black snake slithers along over a rock. You need not jump. None of our common snakes in the United States, not even a rattlesnake, goes out of its way to attack man. But they will defend themselves against attack. The black snake is a good rat and mouse catcher. Here in the sanctuary it will find enough food.

There is a hawk gliding in the air currents. Suddenly he swoops and dives down in the brush. When he rises, he has some small bird in his claws. You thought this was a sanctuary. Why don't they kill the hawk? It is a danger to the other birds.

In a sanctuary, only man is kept from killing plants or animals. All other living things, undisturbed by man, live in balance. Of course, hawks kill some birds and rats and young rabbits. However, they kill for food, not for the sake of destruction. Each animal lives on other living things and keeps the animal or plant it lives on in check. The plants and animals that depend on each other for food make a *food chain.* One food chain you are familiar with is shown in Fig. 249. You can see that the hawk cannot reproduce faster than its food supply, neither can the snake, nor the mouse. In any food chain, reproduction does not exceed the food supply. If the food supply goes up, reproduction goes up also.

Suppose all hawks and snakes and foxes in the sanctuary were killed off. Their natural enemies removed, rats, mice, and rabbits would reproduce in great numbers. They would feed on the bark of trees, and in a short number of years the sanctuary would no

longer be safe for living things. With the trees gone, shelter and food for birds and mammals go quickly. The water and soil is not held back; the rivers choke with mud and the fish die. Living things, you see, live in a delicate balance.

BALANCE ON A FARM

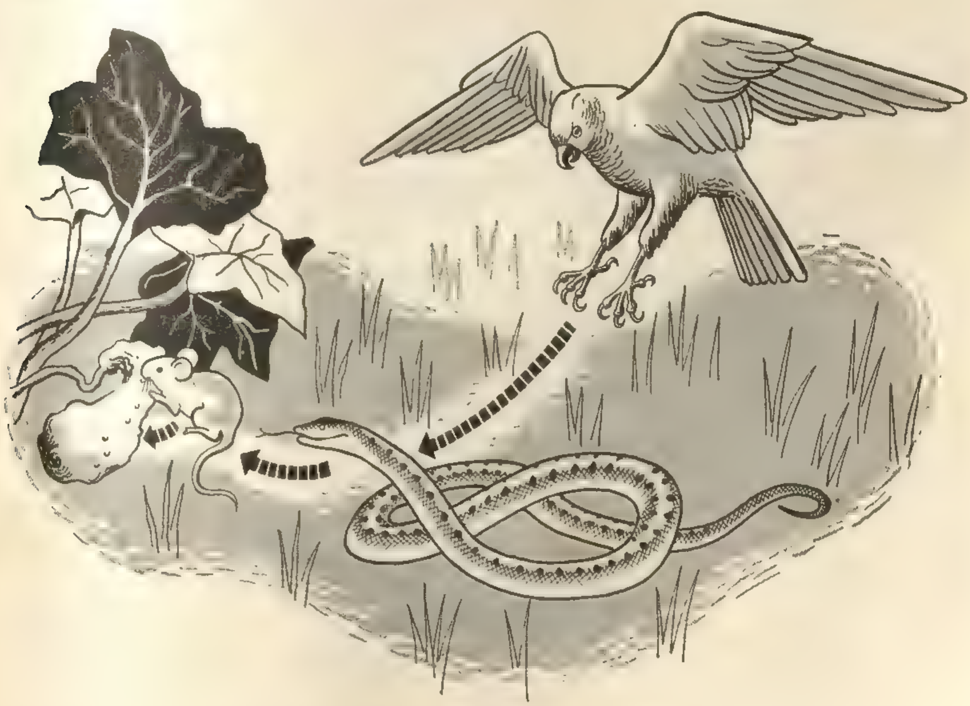
Farmer A removes the thickets of shrubs and trees around his cornfield. He thus drives off the quail that nest in these thickets. They go to a neighboring farm where Farmer B has kept his thickets and wood lot. Next year chinch bugs appear and attack the corn. Farmer A's crop is practically ruined. Farmer B's corn is barely touched. The quail in his thickets feed on thousands of chinch bugs. Naturally, well-fed quail reproduce. Quail help balance the chinch bug and other insects.

ANOTHER DELICATE BALANCE

Here is a small pond in the sanctuary. Probably there are no more than three or four big fish in it. Let us go fishing and catch them all. Soon the big fish are in our baskets. Now what happens?

With the big fish gone, the smaller fish will reproduce in large numbers. They will eat up the pond insects, tadpoles, and water fleas. Now the green water weeds upon which the insects and water fleas feed have nothing to keep them down. They reproduce quickly and soon they have grown into every part of the pond. The water weeds choke the pond. The insects and water fleas die. And the small fish die because they have no food. The animals and plants in the pond no longer balance each other.

The preying animals (big fish) depend on the reproduction of the prey (small fish). These in turn depend on the



249 *A food chain. How does this show a balance in nature?*

reproduction of the insects and plants. Remove any of these entirely and the food chain is broken—the balance is destroyed.

The story we have told you here has been found to occur again and again by scientists working in the fields of conservation. Living things, scientists have learned, live in a delicate balance in nature. When this balance is upset by man, some of the plants or animals die.

As a nation we must insure the reproduction of our wildlife and of our forests. To do this, we must maintain the balance in nature. Then each animal and plant will keep its own numbers and ours will not be a vanishing America.

GOING FURTHER

1 *Insect collection.* Go out into the fields, home lot, back yard. Make a collection of all the insects you can find. In the section "Living Things as a Hobby" (p. 134), you will find references on collecting insects. Exhibit your collection in your science classrooms.

2 *Harmful insects.* If you live on a farm, make a collection of harmful insects that attack crops or cattle. Do you know how to destroy each one of these by poison?

3 *Plant diseases.* If you live on a farm, examine the smut spores on corn, oats, or wheat, or any of the rusts under a microscope. The Yearbooks of Agriculture for 1936 and 1937 describe these diseases and types of plants resistant to them.

4 *Words are ideas.* Can you use these words in a sentence which will give their meaning? Use the glossary.

larva	rust	contact poison
pupa	mold	stomach poison
adult	spore	state conservation commission
spiracles	sanctuary	state forester
nymph	balance in nature	
smut		

5 *Put on your thinking cap.*

1. In a southern state, a bird called the Myna eats cherries and other small fruits, but also eats tent caterpillars and other harmful insects. At the local grange, the planters are discussing a drive against the Myna. What would you say?

2. In Congress, there is a bill to spend one million dollars on scientific research to discover plants resistant to the smuts and rusts. As a citizen, what is your position? Should the bill be passed? Why?

6 *Test yourself.* Read each of the following items and in your notebook add the word or phrase which best completes the sentence. Do not mark this book.

1. The resting stage of insects like the beetle is ....
2. Potato beetles may be best combated by using ....
3. Grasshopper eggs are usually laid in the ....
4. Unlike biting insects, sucking insects are usually controlled by ...... poison.
5. The tiny reproductive cells of fungus plants are called ....
6. Fungus plants cannot grow in canned food because they have been destroyed by ....
7. Salmon are known to spawn in .....
8. In wildlife sanctuaries, animals and plants live together in ....

7 *Adding to your library.*

1. Do you want a map of the Forest Regions of the United States, and a chart of Farm Forest Products? Then write to the "Forester," Agricultural Building, Washington, D.C.

2. Write to the Wildflower Conservation Society, 3740 Oliver Street, Washington, D.C., for a list of wild flowers that need your protection.

3. Get the bulletins from the United States Forest Service, *The Red Menace* and *The Great Forest Fires of America.*

4. *Insects, Man's Chief Competitors* by W. P. Flint and C. L. Metcalf, Williams and Wilkins, 1933, is a small book and is well written.

UNIT SIX

DOING THE WORLD'S WORK

Falling water turns wheels, which turn electric generators, which furnish you with electricity. Electricity lights your home, runs your radio, your refrigerator and freezer, and does many other things to make life easier. But water power, shown here at Grand Coulee Dam in Washington, is only one of man's ways of putting the earth's energy to work for him.

Modern genii

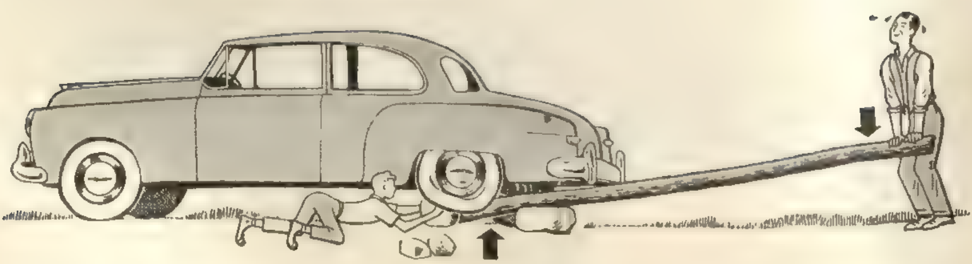
Aladdin rubbed a lamp and immediately a powerful genie was at his command. You, too, have genii, more powerful than Aladdin's, at your command. But you do not rub a lamp, nor do you rely on magic. Instead, you go to a switch on the wall, flick your finger and light floods the room. Or you turn a dial and a radio fills the room with sound from the outer world; you turn a valve which brings gas from your stove to cook your food; you start the family car and thus you have a steel beast of burden. Aladdin and the men of his time never dreamed of workers like these.

It is known now that ten men working in a field, hauling rocks, plowing, pumping water can do about the equivalent work of one horse. In other words, ten men equal one horse in power.

Yet, in your daily activities, using lights, stoves, busses, cars, radios, and eating food cultivated by tractors and delivered by trains, you have the benefits of thousands of horsepower each day. This is equal to the work of tens of thousands of slaves. In other times, wealthy men were judged in part by the number of slaves they had. You are wealthier than many wealthy Romans of the year 100 B.C. You are wealthier than many wealthy Americans of the year 1900.

How has all this come about? How is it that you can obtain horsepower today, by the flick of your fingers?

In this unit "Doing the World's Work," you will learn how man multiplied his own muscles a thousandfold by harnessing the energy in fuels and in electricity. You will learn how man increased his puny energy thousands of times by adopting the ways of science.



250 *A fence rail makes a good lever in an emergency!*

CHAPTER 21

AIDING YOUR MUSCLES

Perhaps you have had the unhappy experience of having a flat tire when you were out riding in the family car. This may happen to anybody. It happened to Mr. Doe and his son one day while they were driving down a country road. What made the occurrence embarrassing to Mr. Doe was that there was no jack in his car; he had lent it to a neighbor the day before. But there was a long fence rail handy and a stone wall nearby. And Mr. Doe was a resourceful man.

He placed a large stone underneath the rear bumper. He then put one end of the fence rail over the stone and underneath the rear axle of the car (Fig. 250). He pushed down on the other end of the rail and easily lifted the car while his son built up a support for the axle with the other stones. The tire was soon changed, the stones and fence rail replaced, and everyone was happy.

Mr. Doe used a lever to lift his car. Scientists have a special name for any device that increases man's ability to do *work*.[1] It is called a "machine." Thus the fence rail that Mr. Doe used as a lever was really a simple machine. It moved a great weight with a little force. To do work, force (a push or pull) must be used to move something.

[1] Work here is used in the scientist's sense. To do work, an object must be moved, or its motion stopped, or the direction of its motion changed.

CONTROLLING ENERGY

To exert force you must have energy —the energy of your body or energy in some other form. Learning what these forms of energy are and how to take advantage of them in the tools we use will help you to understand how the world's work is carried on.

WHAT IS ENERGY?

No one has ever made a completely satisfactory definition of the term *energy*. A good definition is to say that anything with the ability to move itself or to make other things move has energy. You are able to run and play football, basketball, and other games simply because of the energy secured from the good, well-balanced meals you eat. Plants also store up food energy just as animals do. Coal provides energy for moving trains and also the energy to

run factories. Gasoline furnishes the energy to run automobiles and fly airplanes. Falling water has the energy to generate electricity; dynamite, the energy to blast rocks; and uranium 235, plutonium, and even hydrogen the energy to devastate the world (Chap. 13). Wind has the energy to move sailboats and destroy homes in hurricanes and tornadoes; an avalanche, the energy to uproot trees and move rocks; and a rocket, the stored energy to shoot hundreds of miles above the earth's surface. So it goes—you can give countless examples of energy in things that move or that have the power to move other things.

But not all the examples you give would have the same kind or type of energy. For example, would you say that dynamite—not itself in motion—has the same kind of energy as falling water? Would you say that a rocket—not itself in motion—has the same kind of energy as a rocket in flight? Scientists have names for the different kinds of energy that you use. Let's see what they are, so that we can keep our thinking about energy straight.

STORED-UP ENERGY AND ENERGY OF MOTION

Often a body may appear to have no power to exert force at all, but because of its chemical make-up or position it may really have considerable energy. Stored-up energy is called potential energy. *Potential* means possible. Potential energy is energy not visibly in use but able to be used at a later time. Water just at the top of a waterfall has potential energy because of its position. This energy changes into *kinetic* (kĭ-nĕt′ĭc) energy, that is, energy of motion, as the water falls. This kinetic energy in falling water turns turbines at the base of large dams and the moving turbines generate electricity. In the same way, a baseball at the top of its flight has potential energy. When it starts to fall, this potential energy changes to kinetic energy. Its kinetic energy spends itself as it strikes a fielder's glove. An archer stores up potential energy in his bent bow. As he releases the string, the potential energy of the bow is changed to kinetic energy. Thus kinetic energy is given to the arrow.

Dynamite, gunpowder, coal, gasoline, together with other explosives and fuels, contain potential energy because of their chemical nature. This kind of potential energy is often called *chemical* energy. Electricity flowing through a wire possesses kinetic energy. This form of kinetic energy is called *electrical* energy. Coal or other substances that contain potential energy in the form of heat are said to possess *heat* energy. Machines that do work through motion (kinetic energy) are said to possess *mechanical* energy. Waves that travel through space, such as light, radio, ultraviolet, radium, and X rays, possess kinetic energy. The kind of energy present in waves such as these is often called *radiant* energy. But all the kinds of energy we have named are merely varieties of one or the other of the two main divisions of energy—potential, the stored-up energy, and kinetic, the energy of motion.

WHERE DOES ENERGY COME FROM?

If you had to give an immediate answer to this question, what would you say? You might say coal, oil, the earth—and in one sense you would be perfectly right. Yet all the energy that has practical uses in this world of ours has its origin in the sun.

It is the sun's radiant energy that warms the earth and causes water to evaporate into the air and later fall as

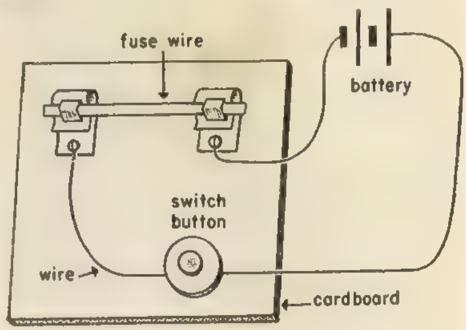
rain. Radiant energy from the sun causes seeds to grow into plants. You have learned that coal, the greatest single source of energy in the crust of the earth, was formed by pressure upon prehistoric plants. These plants grew because of the sun's energy. Petroleum oil was formed as a result of pressure upon the remains of prehistoric plants and animals. Thus petroleum indirectly got its energy from the sun.

Without the sun, there could be little heat or light on the earth. The earth would be a dark planet covered with a layer of solid, frozen air, like ice, but at a temperature hundreds of degrees below zero. All life as we know it would be at an end.

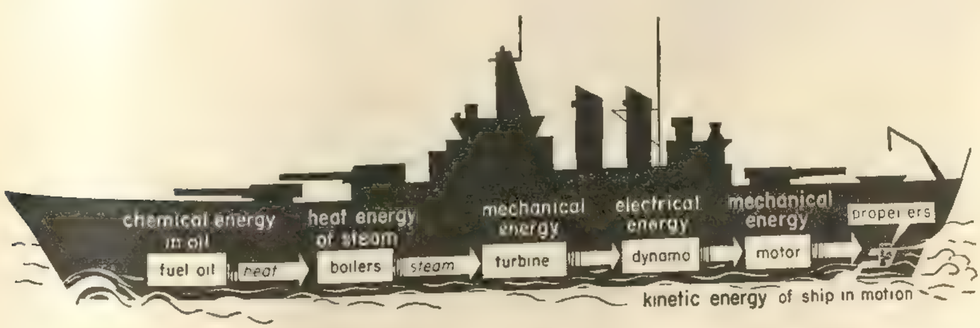
ENERGY CHANGES ITS FORM

Connect a piece of two-ampere fuse wire between the clips as shown in Fig. 251. When you close the circuit with the push-button switch, current from the dry cells will flow through the circuit and cause the fuse wire to melt, thus breaking the circuit. (Caution: Never use house current for this experiment.) Here electrical energy is changed into heat energy. When you press the button of your flashlight, you are changing electrical energy into both heat and light energy in the bulb. In another way, the chemical energy of gasoline is changed into heat energy in the motor of an automobile. In Fig. 252 you will see how the chemical energy of fuel oil is changed to heat energy and finally to mechanical energy that drives a ship.

251 *The fuse wire melts and breaks the electric circuit. Why are fuses necessary in your home wiring system?*



Energy is constantly changing its form. But is it destroyed? That question is answered in the principle known as the law of conservation of energy. This law states: *Energy may change its form but is neither created nor destroyed.* In a ship, the energy originally in the fuel oil changes its form several times, but finally results in giving the ship motion (kinetic energy). To take another example, when you throw a football, you give the ball kinetic energy (Fig. 253).



252 *Heat from chemical energy in fuel oil finally is transformed into the mechanical energy which turns the propellers, which in turn give the ship motion (kinetic energy).*

253 *In making a forward pass, the passer's arm gives the football kinetic energy.* (*Gendreau*)

This kinetic energy is stored in the form of potential energy at the ball's greatest height. As the football falls, the potential energy changes back into kinetic energy. This kinetic energy changes to heat energy when the football strikes the hands of the receiver.

ENERGY AND FORCE

When energy changes occur they are accompanied by *force*. Force is a push or a pull used on an object causing it to move. The energy in steam forces a heavy freight train to its destination. The energy of gasoline forces a heavy truck up a steep hill. The energy of your body forces your bat against a baseball. Mr. Doe also used the energy of his muscles to force his car upward with a lever (p. 369). A certain amount of energy is needed to force a pencil over a sheet of paper. Everyone, every moment of the day, is using force and is seeing force used to do the world's work.

WHEN DO YOU DO WORK?

As you will remember, you can use a great deal of energy and yet do no work, that is, no work in the scientific sense. Have you ever failed to move a heavy stone or a large piece of furniture like a piano? You may have tired yourself out, but the stone or piano remained in the same place. It remained there because the resistance it offered was greater than the force you used.

The resistance of an object to being moved must always be overcome if you want to do work in the scientific sense. *Work occurs only when a force moves an object a certain distance.* Therefore, no work is done unless the object moves some distance when you use force on it.

The resistance of an object to motion is generally due to three things: its *weight*, its *inertia*, or the way *friction* acts on it. Weight is due to the force of gravity. As you remember, the force of gravity acts as if this force were concentrated in the center of the earth. This force holds everything to the earth's surface. To lift a stone you have to reach down and use force to pull the weight of the stone upward against the force of gravity. Thus you do work if you lift that stone.

If you want to push a heavy box to one side, the friction of the box against the floor resists the force you use. You may say that friction in this case is a force you would like to get rid of. But suppose you did get rid of friction? Suppose there were no friction anywhere on the surface of the earth? You would not be able to take a step. You would find it hard to come to a stop. Every movable thing would slide about and unless you grabbed some immovable object or slid into a corner, you would still keep on going.

Even without friction, there is still inertia to contend with. Inertia is of

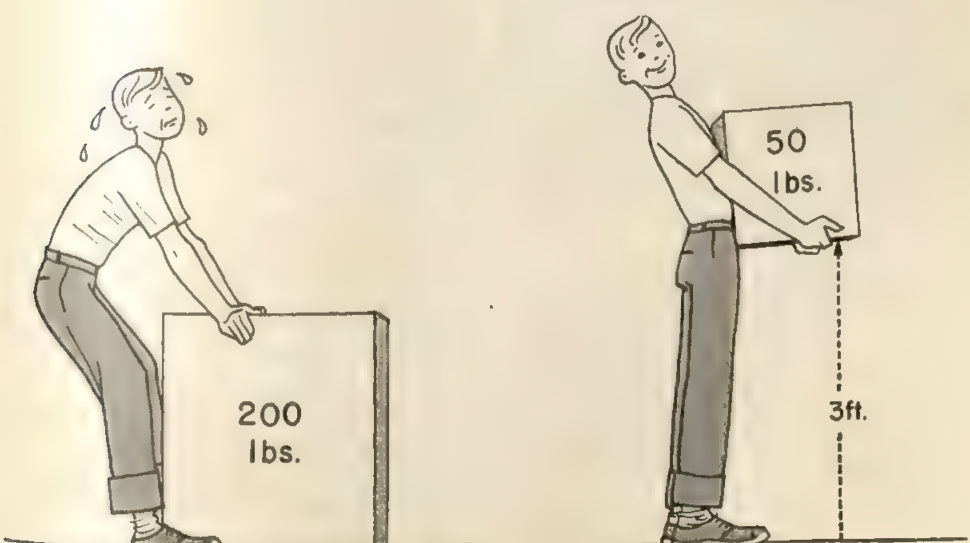
two kinds. It is the tendency of an object at rest to remain at rest until enough force is used to make it move; it is also the tendency of an object in motion *to continue in motion until stopped by another force.* Once a force starts moving an object, the object is kept in motion with less force than was required to start it moving. Have you ever seen men trying to push a car that had run out of gasoline? Once they start the car going it is easier to keep it going with less pushing (force) than was used to overcome the original inertia of the stalled car. Because the car tends to continue moving, it is now difficult to stop it at a gasoline pump. Thus an automobile or a train does not stop as soon as the brakes are applied. The moving vehicle keeps moving for some distance because of its inertia.

So when you lift or push anything—and make it move—you are doing work against: 1. gravity, 2. friction, 3. inertia.

CALCULATING THE WORK DONE

You can measure the work you have done by multiplying the weight of the object (in pounds) by the distance it was moved (in feet). In multiplying feet by pounds, we get foot-pounds. For example, you may have chinned yourself on a bar. You reached over your head and by grasping the bar with both hands pulled yourself up until your chin was over the bar. If you weigh 100 pounds and you lifted yourself two feet, you did 100 × 2 or 200 foot-pounds of work. But no matter how much energy you used to keep yourself chinned you did no work while you remained stationary with your chin on the bar (Fig. 254).

Likewise if you play football in the line as guard and you charge an opponent but do not move him nor does he move you, no work, in the scientific sense, is done. If your opponent weighs 100 pounds, you must do 100 × 2 or 200 foot-pounds of work to move him



254 *Work (in its scientific sense) is done only when an object is* moved *through a certain distance. Is the boy at the left doing any work?*

two feet (neglecting friction).

You see now that work is done only when a force has moved an object a certain distance. Of course, it is much easier to do work when we make use of machines instead of just our muscles. Machines help us to do tasks that would otherwise be beyond our strength. They also help us to conserve our strength and to speed up the jobs we do.

MAKING USE OF MACHINES

If you had lived in the time of the Neanderthal man (Chap. 1), no doubt you would have found just keeping alive very difficult. As ages came and passed, man learned how to use simple things to make life easier. He found he could bring home more meat by dragging it on two poles with the ends over his shoulders. He found that he could use a pole as a pry to move a heavy stone more easily than he could lift or push it. Still later, he found that something that rolled, like a wheel attached to an axle, would move heavy articles still more easily. And so, age by age and step by step, man learned to use simple machines. Today, we find that the parts of the complex machines that do our work are based on the simple machines that primitive man may have used long ago.

WHAT ARE MACHINES?

In the introduction to this chapter, you learned that a machine increases man's ability to do work. Most machines help us to do work by directing or multiplying the force we use. The six simple machines are (1) *levers* such as Mr. Doe used in lifting his car; (2) slopes or *inclined planes* that make it easier to roll or push heavy articles to a height than it is to lift them by brute force; (3) *screws* that lift or fasten heavy weights; (4) *wedges* which with the use of a small force can move or split rock, metal, or wood; (5) *wheels and axles* that can drag or lift mighty objects; and (6) *pulleys* or block-and-tackle arrangements that can move a house.

All complex machines are made of combinations of these six simple machines (Fig. 255). Have you ever seen a Diesel shovel dig tons of earth at one bite and dump the earth into a large truck? Or a crane that lifts and swings great loads from place to place? If you examined these closely, you would find *levers*, *inclined planes*, *screws*, even *wedges* on the locks of the shovel or crane, as well as *wheels and axles* and *pulleys* to lift and move the load.

Still other machines change the direction of the force used. Your bicycle is one such machine. You press downward alternately on one pedal and another to move in a forward direction. You wind your watch in a motion at right angles to the motion of the hands. The pistons in an automobile engine move up and down, but the car goes forward. Most machines—simple or complex—are designed to do useful work for a useful purpose.

HOW DOES A LEVER HELP US DO WORK?

For this simple experiment you need a ruler, an eraser, and a book. Place your finger underneath the edge of the book and raise it slightly, testing its weight. Now place the end of the ruler over the eraser and underneath the edge of the book. With your finger press down on the other end of the ruler. Can you lift the book more easily with the ruler than with your finger alone? Now move the eraser toward the middle of the ruler and press down on the ruler again. Can you raise the book as easily as before?

255 *Notice the pulleys and cranes used in laying this pipe line. How many simple machines can you recognize in this photograph?* (*Caterpillar Tractor Co.*)

The ruler as you used it was a lever. Notice that the lever was supported at one place (the eraser), while a *force* (the push of your finger) was applied at another place. The force acted against a weight or *resistance* (the book) at a third place on the lever. The point at which the lever was supported (the eraser) is called a *fulcrum.*

Levers are divided into classes depending upon where the *fulcrum,* the *force,* and the *resistance* are located (Figs. 256, 257, 258).

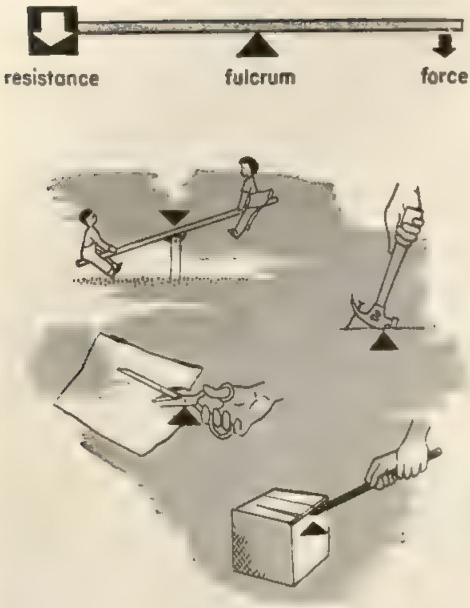
Now you can apply this knowledge to your own experiment.

1. The ruler, as you used it, was a first-class lever. The fulcrum, the eraser, was between the force represented by the pressure of your finger and the resistance represented by the book.

2. When you lifted the book with your finger, you found its weight much greater than the force you applied to the end of the ruler. That is why small forces can move heavy objects and why Mr. Doe was able to lift his car with the fence rail. A first-class lever is a machine that helps us move heavy objects with a small force.

3. You noticed also that the distance you moved the end of the ruler was much greater than the distance the book was lifted. In other words, when you use a small force to move a heavy object, the distance the force moves is much greater than the distance the object moves (Fig. 259).

4. You also noticed that when you moved the eraser (the fulcrum) toward your finger, the distance your finger moved the ruler became shorter and the force you used to lift the book became greater. You would conclude that in order to lift a heavy object with a



256 *Four examples of first-class levers. In each, can you point out the force, fulcrum, and resistance?*

little force, the fulcrum should be as close as possible to the heavy object (Fig. 259).

Certainly it is an advantage to increase your ability to do work by the use of a simple machine like the first-class lever. Scientists have a special name for the advantage that any machine gives us in doing work. It is called the *mechanical advantage* of that machine. The advantage Mr. Doe got in lifting his car by using a lever (p. 369) or the advantage you got in using a ruler as a lever is the mechanical advantage.

But no matter how great the mechanical advantage of your machine, *the work you put into it equals the work you get out of it;* that is, neglecting friction. Mr. Doe had a fence rail, the end of which he pushed down six feet with a force of 100 pounds in order to lift one side of the rear end of his car (weight 600 pounds) one foot from the ground.

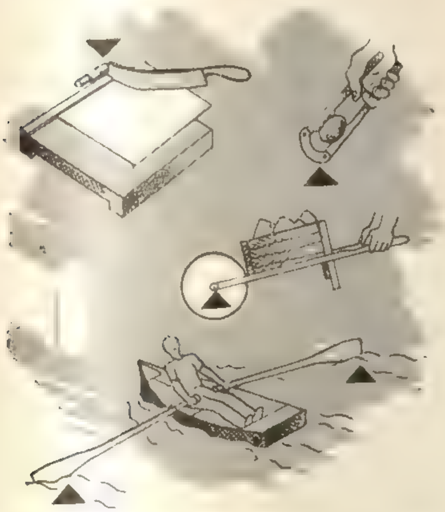
So you see, no work (as scientists use the term) is saved by the use of a lever, or in fact by any machine. The machine always makes the work you put into it easier to do. Certainly Mr. Doe was thankful for his machine—the fence rail (lever) and rock (fulcrum).

THE INCLINED PLANE

The inclined plane is one of the oldest and simplest devices that make work easier to do. The truckman often finds it easier to roll a heavy barrel up a sloping platform to the bed of his truck than to lift the barrel vertically. Primitive man also found it easier to roll a heavy stone up to his cave rather than to lift and carry it. Any sloping surface is an inclined plane. Now look at Fig. 260. You will see why an inclined plane is a machine that makes the work easier to do.

Suppose somebody gets on a sled and you draw the sled up a sloping hill fifty feet high. Disregarding your own weight, you will agree that it is certainly much easier to draw a weight of 100 pounds up a long slope than to lift 100 pounds vertically 50 feet! With a force of only 20 pounds neglecting friction you might draw the 100-pound

Force Mr. Doe used	×	distance end of fence rail was pulled down	=	weight of one side of rear end of car	×	distance this weight was lifted
↓		↓		↓		↓
100 lbs.	×	6 feet	=	600 lbs.	×	1 foot
600 ft. lbs. of work put in			=	600 ft. lbs. of work done		



257 *Four examples of second-class levers. Where do you find the fulcrum, force, and resistance in the paper cutter, nutcracker, wheelbarrow, and boat?*

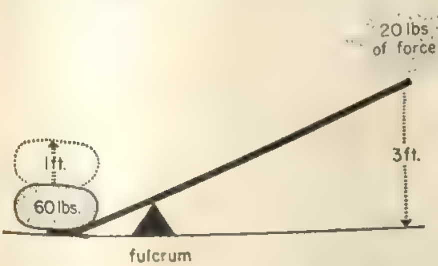
258 *Three examples of third-class levers: man hoeing, woman sweeping, boy shoveling. Point out the force, fulcrum, and resistance in each.*

load 250 feet from the bottom to the top of the hill.

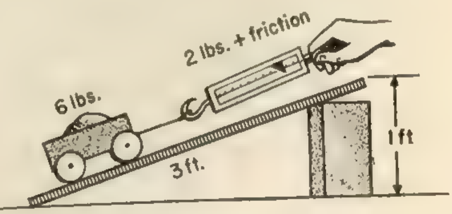
EFFICIENCY

But we cannot neglect friction in any machine. Friction adds resistance to the work you put in. If you could actually measure the amount of force you used in the above example, you would find that it might be nearer 25 pounds than 20 pounds. The extra five pounds is used in overcoming the friction of the sled runners against the snow.

Thus no matter what the machine,



259 *With this lever 20 pounds of force applied through a distance of 3 feet can lift a weight of 60 pounds 1 foot. Can you see now why Mr. Doe used a long fence rail as a lever?*



260 *On this inclined plane you pull a little car and its load totaling 6 pounds a distance of 3 feet to a height of 1 foot. The force required is about 2 pounds.*

you never get exactly the amount of work out of it that you put into it. For a good deal of the work done by any machine must be done to overcome friction. For that reason scientists are interested in the *efficiency* of a given machine.

Efficiency is measured by dividing the work the machine does by the work put in, or

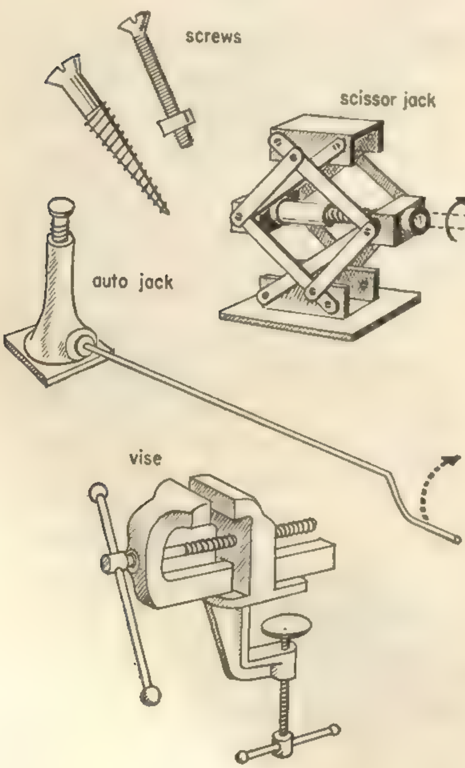
$$\text{Efficiency} = \frac{\text{Work done}}{\text{Work put in}}$$

For instance, by using an inclined plane such as the one shown in Fig. 260 6 foot-pounds of work are done. But 8 foot-pounds are put in because of the need to overcome friction. Thus

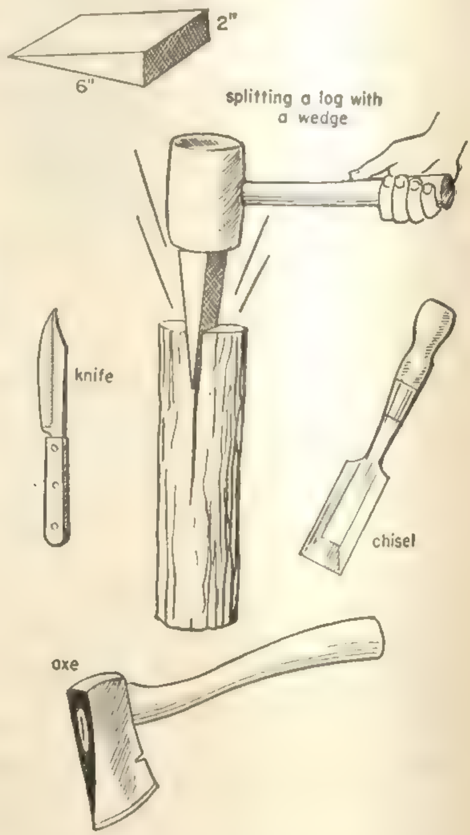
$$\text{Efficiency} = \frac{\text{Work done}}{\text{Work put in}} = \frac{6}{8} = 75 \text{ per cent}$$

You will realize that since the work put into the machine is always greater because of friction, the work done must always be less than the work put in. Thus you will never get a machine that is 100 per cent efficient.

Most machines are less than 80 per cent efficient. But because they are so necessary for making work easier to do, we can afford to pay for the extra work we put into them. For example, the gasoline bulldozer is only about 18 per cent efficient. That is, only 18 per cent of the energy of the gasoline we put in does useful work. Yet who would want to move a hill by hand? So we pay for the extra gasoline that produces the energy for the bulldozer to level the hill.



261 *Screws fasten as well as raise heavy weights. Do you recognize these?*



262 *The wedge is one kind of inclined plane. Here are several useful wedges.*

SCREWS CAN MOVE AGAINST GREAT RESISTANCE

Have you ever examined a metal screw carefully? If you have, you have noted these things about it:

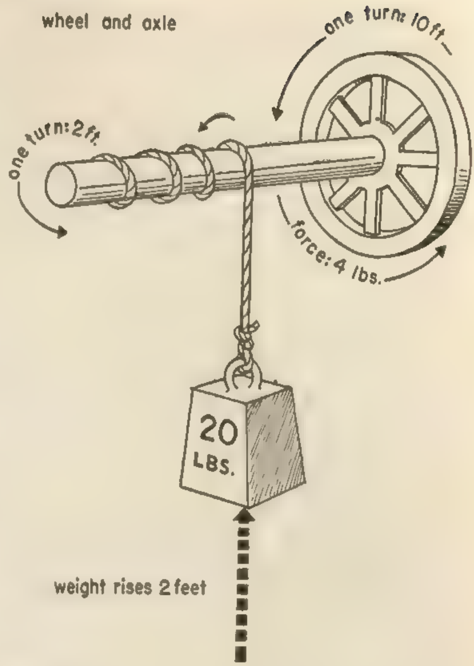
1. The screw is simply a metal rod with a winding spiral ridge cut in it from top to bottom (Fig. 261).

2. The edges of the spiral ridge may be close together or may be some distance apart.

When the distance between the ridges or threads of the screw is small, there are more threads per inch than when the distance between the threads is greater. The "pitch" of a screw is the distance between the threads. The more threads there are on a screw, the smaller the pitch. When you use a screw with a small pitch, you must turn the head of the screw a greater number of times to make it sink into wood the same distance as a screw whose pitch is large. Large jacks for lifting hundreds of tons of weight are really little more than screws with a small pitch. But they can lift heavy weights.

WEDGES ARE SIMPLE MACHINES

Do you know what a wedge is? Examine Fig. 262. You will notice that in each case the wedge is thick at one end and tapers evenly to the other end. Each side of the wedge, therefore, is an inclined plane. A wedge is a machine that can move against heavy resistance, or move a heavy weight by being driven against the resistance. Thus a small wedge can split a large log, if the wedge is of the right length and thickness. If the wedge is six inches long and two inches thick at the heavy end, it can be driven six inches into the log while forcing part of the log two inches apart. Unless the log is long, this is usually sufficient to split the log into two pieces.



263 *Wheels and axles are parts of many of today's machines. Have you ever seen a wheel and axle being used to raise water from a well?*

WHEELS AND AXLES

If you have ever brought water from a well by means of a windlass, you have used another simple machine, the wheel and axle (Fig. 263). Notice in the figure that the weight is attached to the axle by a rope. Force is applied to the outside part of the wheel. Every time the wheel is turned one revolution, the axle also makes one revolution. But the circumference of the axle is much smaller than the circumference of the wheel. Hence, a small force applied to the outside of the wheel can lift a heavy weight that is attached to the axle.

Common examples of the wheel and axle are the wheel that hoists ladders on fire trucks, a reel that winds up a garden hose, your fishing reel, an auto-

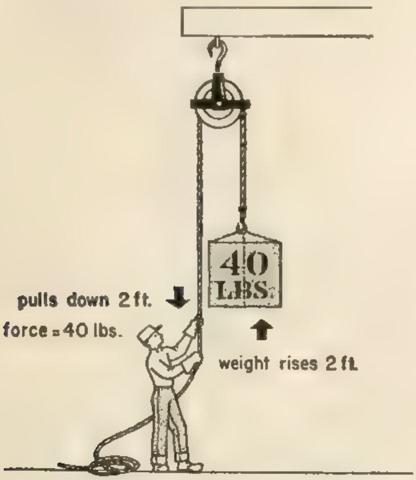
mobile steering wheel, the hand brake wheel on top of a freight car, and even a doorknob.

PULLEYS AND THEIR ARRANGEMENT

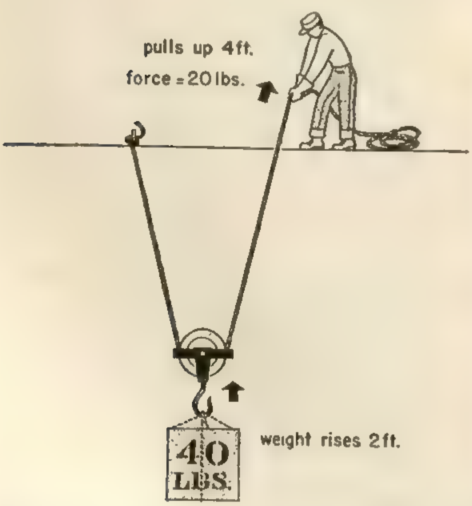
How do you pull up the curtain on the upper half of a school window? The cord runs over a pulley fixed at the very top of the window. Of course, you pull down as much cord as the distance required to raise the curtain. The only advantage of a machine like the fixed pulley is that it allows you to stand on the ground and lift things far above your head, or to change in other ways the direction of the force you use (Fig. 264).

However, there are other pulleys that enable you to move heavy weights. For instance, a movable pulley of the kind shown in Fig. 265 allows the weight to be moved two feet while the force or pull moves four feet.

With two sets of pulleys (block and tackle), such as those shown in Fig. 267, extremely heavy weights can be lifted or moved with little force. For the heaviest weights, extremely heavy blocks such as the one shown in Fig. 266 may be used. Of course, the force must travel a long distance compared with the weight.

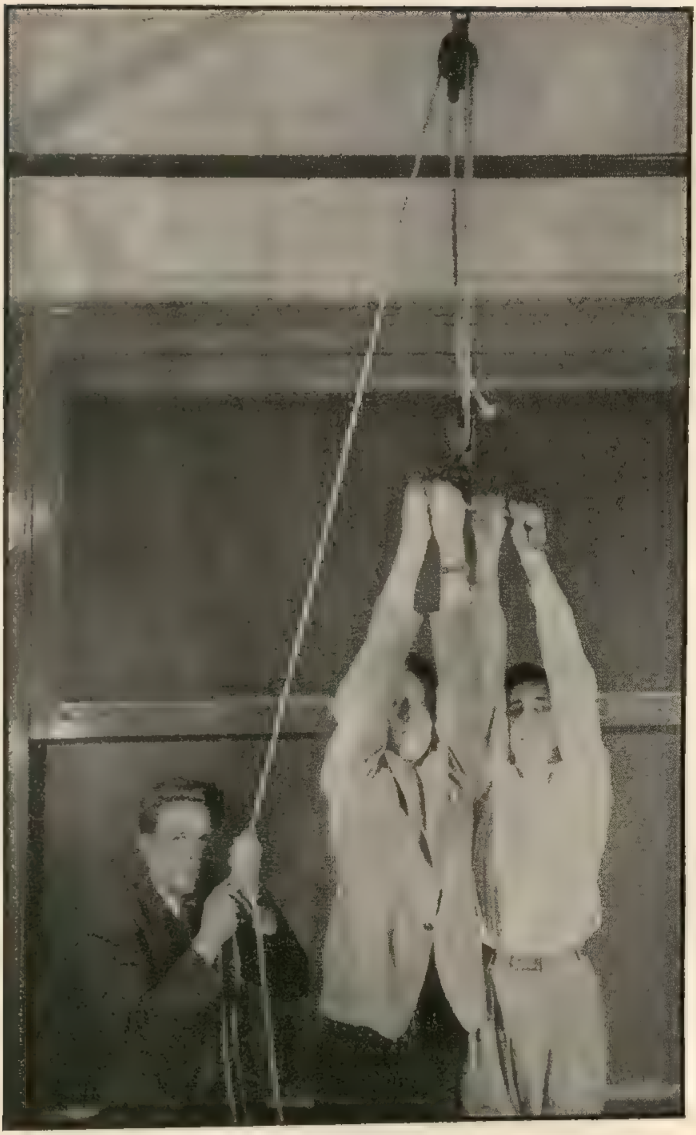


264 *Pulling downward is easier than lifting. Why are pulleys placed at tops of window curtains in schoolrooms?*



265 *This movable pulley would be suitable for lifting a bundle of shingles to a scaffold below the workman.*

266 *This block is used as part of a block and tackle (a pulley system) to lift the heaviest weights. (Whiting Corp.)*

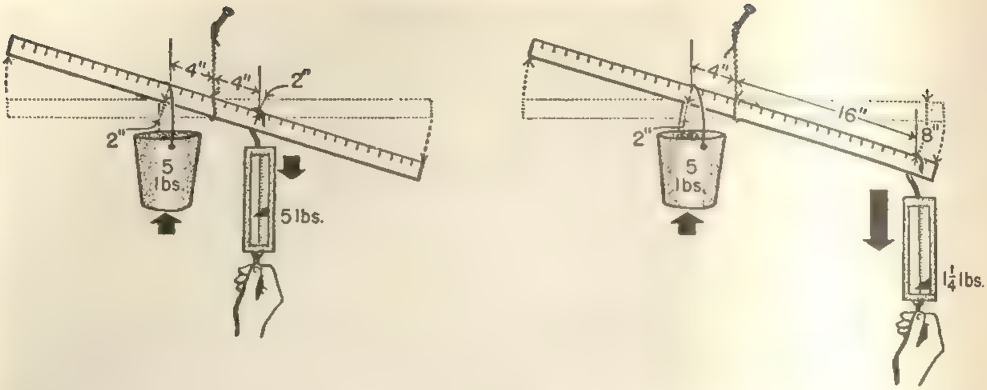


267
Here one boy is lifting two boys, whose combined weight is three times his, by using a single and double pulley. (Science Department, Brookline High School, Brookline, Massachusetts)

LOOKING AHEAD

You have now become acquainted with the way man multiplies his muscles and the way he uses some machines in doing his work. The six simple machines mentioned in this chapter help man do work in countless ways, separately and together. For example, a lever such as a crowbar is one of the farmer's most useful tools. A clock is composed principally of levers and wheel-and-axle mechanisms. A bulldozer, a gasoline shovel, or a crane use combinations of simple machines. And if you study more complex machines, such as the printing press of your daily newspaper or presses that print books such as this, you can still pick out the separate parts that are the simple machines you have just studied.

In the factory, farm, or in your daily tasks, time is very important when work



268 *In a first-class lever, the force needed to move the resistance becomes less as the distance of the force from the fulcrum increases. Why is a force of only* $1\frac{1}{4}$ *pounds needed to lift the 5-pound pail in the right-hand drawing?*

is being done. Of course, you may take a day or a month, if you wish to move one ton of earth from one place to another. The amount of work you do is the same. But if you were paying for the job, you'd want it done in the quickest time possible. Thus men are interested in doing work quickly. That is, they are interested in the rate of doing work, in how long it takes to do a certain amount of work. The rate of doing work is called *power*.

Power helps us to reduce the time in which a job is completed. You may walk two miles to school in 25 minutes. Years ago you might have gotten there more quickly by using the added power of a horse. Nowadays, you may get even more power by using an automobile or bus. Man has not only multiplied his muscles, but he has also increased the speed with which he uses them. He has achieved more power. And power is just what we shall discuss in the next chapter, "Quest for Horsepower."

GOING FURTHER

1 *Making a teeterboard—a first-class lever.* Make a teeterboard by placing the middle of a plank about 12 feet long over a saw horse. Let one person get on the plank one foot from the saw horse. Exert enough force three feet away from the other side of the saw horse to raise the other end of the plank from the ground. Now do the same six feet away from the saw horse. In which position did you use less force? In which position did the force move farther?

2 *Experimenting with levers.* With a heavy string, suspend a yardstick from a ring stand or nail driven into an upright (Fig. 268). Hang a small pail on a spring scale and pour enough water into the pail to make it weigh five pounds. Now hang the handle of the pail over one end of the yardstick four inches from the supporting string. With the hook of the spring scale over the other side of the yardstick four inches from the string, pull downward until the pail is lifted about two inches (Fig. 268). Read the scales as you pull. Now move the spring scale over to the farther end of the yardstick and again pull downward until the pail is lifted about two inches (Fig. 268). Read the scale. How does this show that you increase your ability to do work by the proper use of a lever?

3 *Experimenting with pulleys.* From a wooden frame hang small pulleys and a small block and tackle supplied from your school laboratory as in Fig. 269. With a

five-pound pail of water as the weight and your spring balance to measure the force used, record the following data for each type of pulley:

1. The reading of the spring scale compared with the weight of the pail.

2. The distance the weight moves compared with the distance the force moves.

You have been given an idea of the force which will be needed to lift the five-pound weight with the first type of pulley (A, Fig. 269). How much force will be needed if you used the pulleys shown in B and C? Can you discover a relationship between the force needed and the number of strings supporting the weight to be lifted?

4 *Words are ideas.* Can you use these words in a sentence which will give their meaning? Use the glossary.

potential energy	wheel and axle
kinetic energy	first-class lever
chemical energy	second-class lever
electrical energy	third-class lever
heat energy	inclined plane
radiant energy	block and tackle
machine	fulcrum
friction	screw
inertia	pitch
work	

5 *Put on your thinking cap.*

1. Make a diagram showing:

(*a*) How you would use a lever to lift one side of the rear end of a car (weighing 600 pounds) a distance of one foot with a force of 100 pounds.

(*b*) How long an inclined plane you would use to lift a 100-pound barrel two feet, when you use a force of only 20 pounds.

(*c*) The pulley system you would use to lift a weight of 400 pounds with a force of 100 pounds.

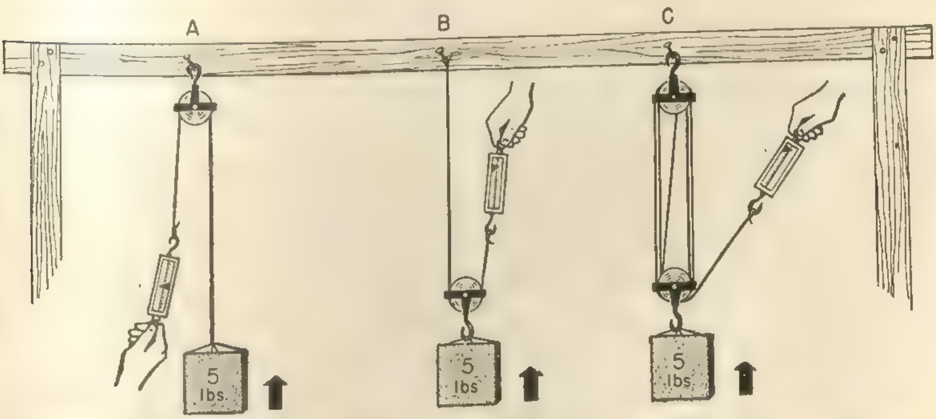
2. How much work do you do if you weigh 100 pounds and walk up a flight of stairs 10 feet high?

3. The efficiency of a certain simple machine is 80 per cent. If the work put in is 100 foot-pounds, what extra work was done in overcoming friction?

$$\text{Efficiency} = \frac{\text{work done}}{\text{work put in}}$$

4. What sort of simple machine could you use to:

(*a*) haul a flag up a flagpole
(*b*) drag a heavy boat on shore
(*c*) put a 400-pound barrel of vinegar into a trailer truck
(*d*) pry up a large boulder
(*e*) move a 50-pound load 200 feet
(*f*) lift a large block of granite
(*g*) haul up water from a well with a pail
(*h*) split an oak log



269 *Which arrangement of pulleys makes it easiest for you to lift a 5-pound weight?*

6 *Test yourself.* In your notebook, complete these sentences with an accurate word or phrase. Do not mark this book.

1. Energy of motion is called ...... energy, while stored energy is called ...... energy.
2. Any device that helps man do work is called a ....
3. A first-class lever has the ...... between the ...... and resistance; a second-class lever has the ...... between the force and ......; a third-class lever has the ...... between the fulcrum and ....
4. The six simple machines are ......, ..., ..., ..., ..., ...
5. Three factors that oppose work are ......, ... and ....
6. The amount of work done divided by the amount of work put in gives us the ...... of a machine.
7. The distance from one thread to the next in a screw is called the ....
8. A woodsman has ..... at hand, as well as an ax, for splitting heavy logs.
9. A wheelbarrow is an example of a ...... class lever.
10. A brake wheel on top of a freight car is an example of a ...... and ....

7 *Adding to your library.* You might like to read *Boys' Book of Science and Construction* by Alfred P. Morgan, Lothrop, Lee and Shepard, 1948. It gives some excellent suggestions for experimenting. Chapter 3 will give you some suggestions for experimenting in the field of mechanics.

CHAPTER 22

QUEST FOR HORSEPOWER

If you could have been in Alexandria, Egypt, on a hot summer's day almost 2,000 years ago, you might have witnessed one of the first attempts that anyone ever made to change heat energy into mechanical energy. In other words, you might have seen the first steam engine ever built. It was a simple thing, this engine. Yet it was one of the most amazing inventions of its time.

A young man named Hero had often boiled water in a pottery jar. Noticing that the force of the steam kept lifting up the cover as it escaped, he reasoned that if the steam could push up a cover, it might be made to do work for man. Steam might even be made to move an object by pushing it against the resistance of air. So Hero constructed an engine that looked something like the one in Fig. 270.

Hero attached two bent metal tubes to opposite sides of a hollow ball. He mounted the hollow ball upon an axle

so that it would move freely. Then he filled a boiler half full of water and built a wood fire under it. The steam, rushing out of the ends of the bent tubes connected to the boiler, set the ball turning in the same way water rushing out of the bent arms of a lawn sprinkler sets a sprinkler in motion. This motion is caused by the force of the stream of steam or water producing an opposite reaction on the ball or lawn sprinkler.

Hero's tiny engine was the first ever invented to make use of the energy of steam. Of course, it was just a toy, but to the people of Alexandria it was a marvelous thing that turned by itself without using the strength of men or horses. Hero's fuel was wood, and wood remained the principal fuel until the nineteenth century.

Today we have many different kinds of fuels. We also have complex engines which make use of these fuels. But the search for fuels and engines to use them has not ended. Today the search continues for engines that will make use of the energy released by atomic fission. Even as you read this, engines for using atomic energy are being built.

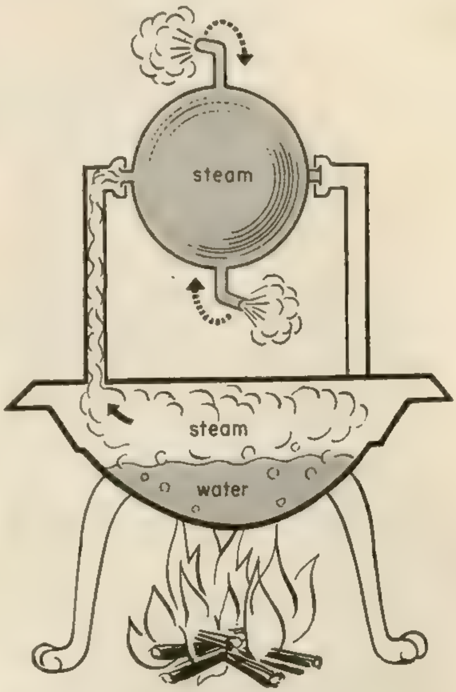
In this chapter, you will learn how fuels produce energy and how this energy is used in operating machines. You will see some of the effects these machines have had on civilization. You will understand the important effect of power on your life.

FUELS AND ENGINES

Any fuel burns when it is heated to the temperature where it will ignite. This temperature is called the *kindling temperature* of the fuel.

TO LIGHT A FIRE

Fuels have different kindling temperatures. For example, the heat of friction will ignite a match. The heat of a burning match will cause paper, which has a higher kindling temperature than a match, to catch fire. Wood, which has a higher kindling temperature than paper, can be ignited by the



270 *Hero's steam engine. Why does the ball turn?*

heat of burning paper. Coal with a still higher kindling temperature than wood can be ignited by the heat of burning wood. Coal fires are usually ignited by these steps because the heat from a burning match is not great enough to set fire to a piece of coal.

On the other hand, gaseous and liquid fuels, such as illuminating gas, natural gas, alcohol, gasoline, and kerosene, have very low kindling temperatures and can be ignited easily by the heat of a burning match.

HOW DO FUELS BURN?

Most fuels contain carbon either alone or in compounds containing hydrogen and carbon. When the kindling temperature of these fuels is reached and if there is sufficient oxygen, the carbon burns completely to make carbon dioxide and the hydrogen burns completely to make steam, as follows:

hydrogen + oxygen → steam (H_2O) + heat
carbon + oxygen → carbon dioxide (CO_2) + heat

In the burning of fuels containing carbon and hydrogen, a great deal of energy in the form of heat is given off. The more heat given off for each pound of fuel, the more valuable that fuel is in operating machines. For example, gasoline has four times the heat value of dry wood and one and one third times the heat value of coal. Coal is used instead of wood to operate steam engines because it has three time the heat value of wood. In the order of their heating value you have:

dry wood—heat value per pound = 1
coal —heat value per pound = 3 times wood
gasoline —heat value per pound = 4 times wood

Solid fuels, like coal, burn slowly giving off their heat for a long period of time. On the other hand, gaseous fuels, such as illuminating gas and natural gas, if mixed with air in a closed space, may explode when the mixture is ignited. Liquid fuels, such as gasoline, that form gases easily are used to produce explosions in gasoline motors in this way. It is extremely dangerous to light a match in any room into which gas may have been escaping or where explosive cleansing fluids have been used. Gasoline, when mixed with air, has more explosive force than dynamite pound for pound. It should never be used indoors for cleaning because someone may be forgetful and light a match.

DO FUELS BURN COMPLETELY?

Have you ever examined a gas stove burner? In the pipe, behind the burner, there is a hole. As the gas passes by this hole in the pipe, air enters and mixes with the gas. When this air-gas mixture is ignited, there is enough oxygen in the gas mixture to burn the hydrogen and carbon of the gas. When hydrogen and carbon burn completely, water and carbon dioxide are formed. All the heat value of the fuel is given off.

It makes a difference what method is used to burn a fuel. In a coal furnace much of the heat of the fuel goes up the chimney. Modern boilers are built in such a way that this heat passes back and forth in the furnace under water jackets or tubes before going up the chimney. In this way, heat is saved. Blowers are sometimes used to force air through burning coal to get most of the heat from it and leave very little ash. Newer methods of saving the heat energy of coal for producing power have given us more efficient locomotives and electric power plants.

Gasoline is never completely burned in automobile engines. Gasoline is a compound of hydrogen and carbon. When it burns incompletely, carbon, a solid, and carbon monoxide (CO), a poisonous gas, are formed. The hydrogen in the gasoline unites with oxygen from the air. Some of the carbon unites with oxygen to produce carbon dioxide. Some carbon does not combine with oxygen completely and burns to carbon monoxide. The rest of the carbon, unable to burn, coats the inside of the engine. Perhaps you have heard your father say, "I think I'll have to take the carbon out of the car." When much carbon forms inside the top of the motor,

the engine no longer operates smoothly.

Carbon monoxide, a deadly poison, is also found in illuminating gas. Therefore, extreme care should be used to see that every gas burner in your home is safely turned off when not in use. Not a week goes by without some reports in newspapers of persons being overcome by carbon monoxide from illuminating gas in homes or from the exhaust of automobile engines in closed garages.

Fuel oil, used in stoves and furnaces, produces more heat than coal when it is properly burned. Again, much of the heat goes up the chimney. Today different grades of fuel oil furnish heat to power battleships, steamships, railroad trains, truck engines, and furnaces. Improvements are being made to make fuels burn more completely to get the greatest amount of energy from them.

Today's modern machinery is a long step from Hero's tiny steam engine of almost 2,000 years ago. Still, it was not until the invention of a useful steam engine in the eighteenth century that man realized he had at his finger tips a way to make heat energy a source of power.

THE FIRST STEAM ENGINE

Thomas Newcomen, an English blacksmith who lived in the early part of the eighteenth century, was the first person after Hero to make successful use of the energy of steam. Unlike Hero, Newcomen devised an engine that would actually do useful work for man. It looked something like the one in Fig. 271.

Newcomen knew that steam occupies 1,700 times as much space as the water from which it came. He thought of allowing this steam to escape into a chamber where it would push a piston upward. Then the steam would be condensed by a jet of water squirted into the chamber through a valve (B). Then another valve (A) would open to allow more steam to enter the chamber and the process would be repeated. By attaching the arm of a beam to the other side of the piston, Newcomen was able to pump water out of coal mines (Fig. 271).

JAMES WATT AND THE AGE OF STEAM

There were a number of drawbacks to Newcomen's engine. The greatest was its inefficiency. It wasted much of the heat energy of steam by condensing the steam with cold water. The valves had to be turned by hand. It had nothing to control its speed except the quickness of the operator. He had to move his hand from valve to valve as the piston moved up and down.

Newcomen's engine was invented in 1705. Not until 1768 was James Watt, one of the greatest of England's scientists, able to make improvements on Newcomen's invention. He found a way to get rid of the hand-operated valves. Through the years that followed, he discovered ways of conserving the valuable heat energy of steam. He found ways to control the speed of the engine. And he invented a safety valve for the boiler so that it could not blow up.

James Watt's invention came just at the time industry was ready for power. In Fig. 272 you will see how his steam engine finally developed.

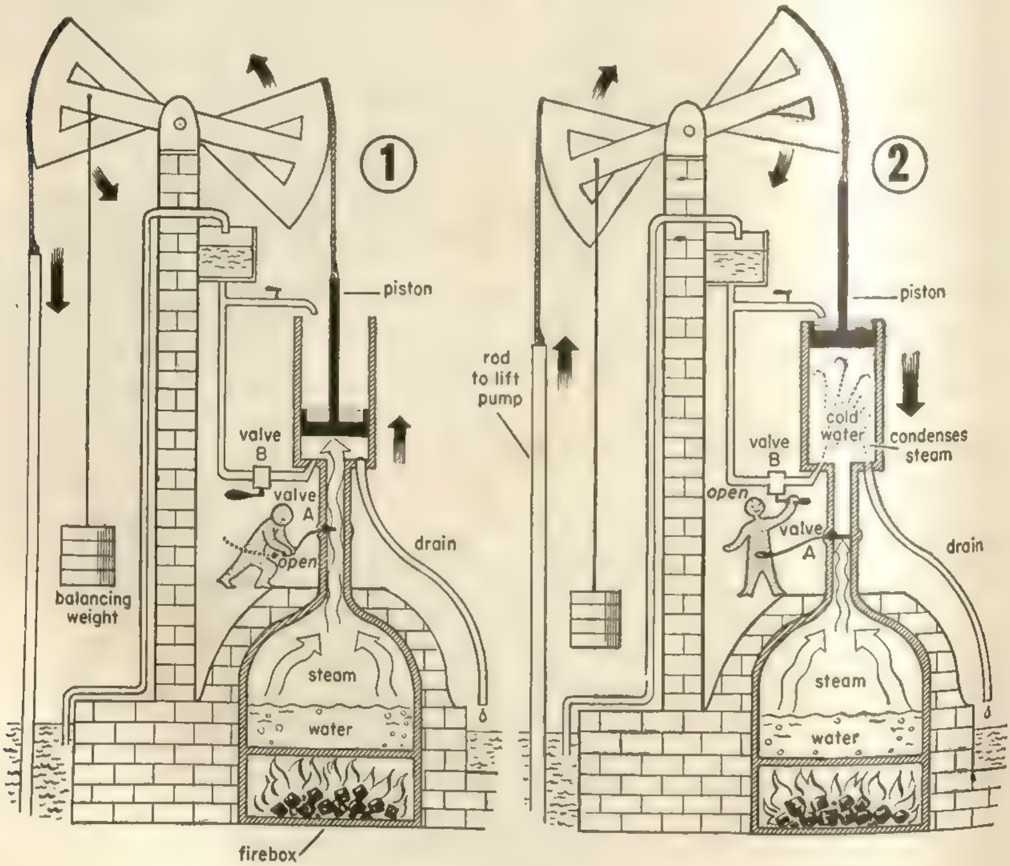
STEAM STARTS AN INDUSTRIAL REVOLUTION

James Watt died in 1814, but not before he had seen his steam engine start the greatest revolution the world has ever known. In the eighteenth century, England's most important industry was the spinning and weaving of cloth. New inventions for spinning

and weaving appeared but they required more power than was at hand. More and more coal was needed to supply this power. Fortunately, the power from Watt's engine permitted more coal to be mined. The coal was hoisted from the mines to be burned in the steam engines of distant mills. People who had done their weaving on small hand looms moved to cities where miles of cotton and wool cloth were being woven daily in great factories. As this revolution in methods of manufacture spread, more and more of the world's population became concentrated in cities where manufacturing plants could get transportation and fuel and cheap power.

James Watt's steam engine was a stationary engine; that is, it stayed in one place and did work. But George Stephenson, an English engineer, put the stationary steam engine on wheels. In 1814, Stephenson actually succeeded in hauling ten coal cars at the dizzy speed of four miles an hour! Thus the first locomotive was born. Soon steam was used to push boats through water.

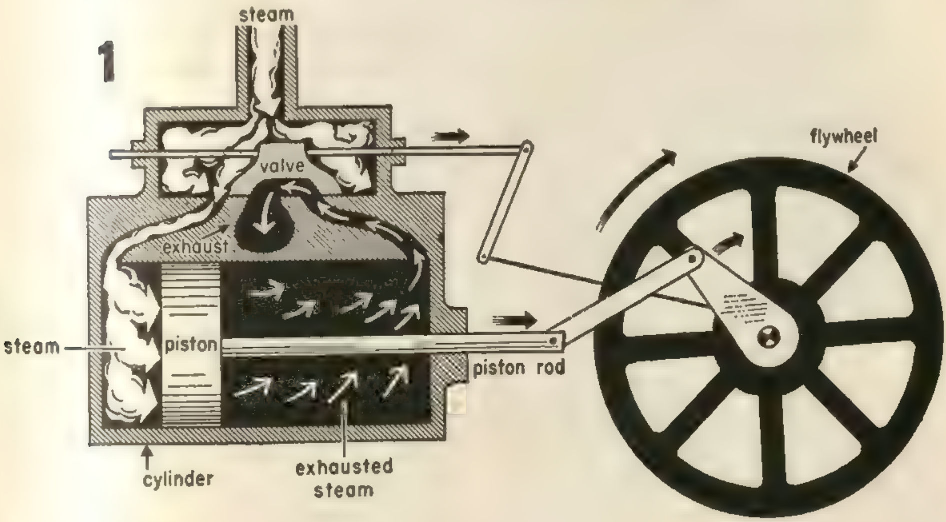
Imagine youself among a crowd that gathered on the banks of the Hudson River in 1807. You would have been amazed and perhaps somewhat fearful to see a ship without sails belching forth flame and smoke. Yet it was moving up

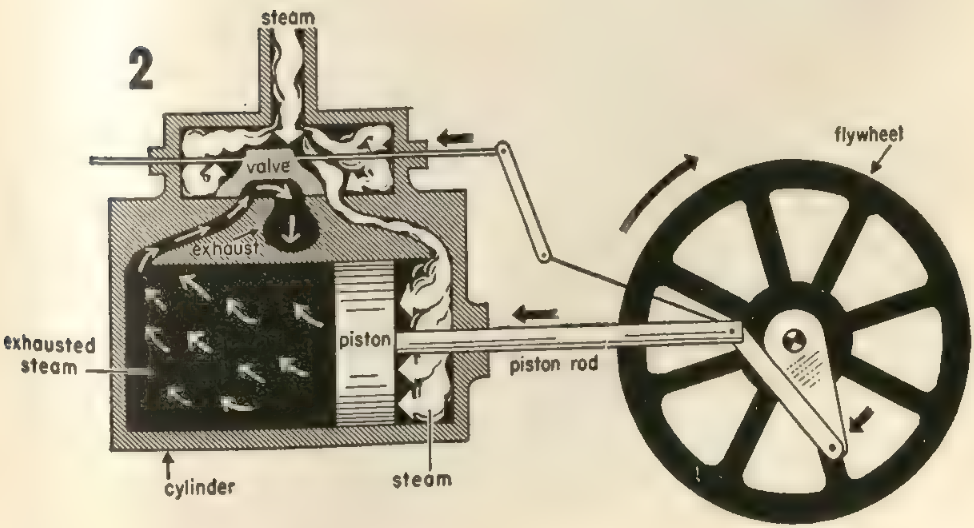


271 *Newcomen's steam engine. One disadvantage was that the valves had to be turned by hand, so the steam engine worked very slowly. What other disadvantages can you see?*

the river against tide and wind. Although other ships had previously used the power of steam to move successfully against both wind and tide, the "Clermont," Robert Fulton's ship, was one of the first to achieve success. He had taken care not to repeat the mistakes of other inventors.

272 *In Watt's perfected steam engine, the slide valve regulates admission of steam to the cylinder.* (Above) *The slide valve moves to the right, allowing steam to rush into cylinder ahead of piston, forcing piston to the right. This moves the flywheel.* (Below) *The slide valve moves to the left, allowing steam to rush into cylinder to the right of the piston, forcing piston to the left. This continues the motion of the flywheel.*





PARSON'S TURBINE

The steam engine Watt invented, and others built like it, wasted a great deal of the energy of steam. Not all of the heat energy in the steam was used up before the waste steam was exhausted from the engine.

About 60 years ago Charles Parsons, another English engineer, thought of a way to get more power from steam. He made a machine that looked like a series of windmill blades of different sizes, one behind the other. Some of these windmill blades were attached to a central shaft and could turn with the shaft. Others were stationary and were placed to direct a flow of steam against those blades that could turn. The blades were carefully built to use up the energy of the steam as it passed from one row of blades to the next.

When this engine was tightly enclosed in an outer shell, the steam entered the shell at high pressure and temperature. When the waste steam came out, it had given up most of its heat energy. Meanwhile this energy had been used to make the shaft of the machine turn at high speed. Parsons found that his machine, called a turbine, would run constantly at a speed of 18,000 revolutions per minute just as long as high-pressure steam entered it. Moreover, for its size and light weight, it produced an amazing amount of power. Most steam turbines today produce over 20 times the power of Parsons' first model.

An ordinary steam engine may be about 10 per cent efficient. A steam turbine may be about 60 per cent efficient at a high speed. However, the steam turbine becomes quite inefficient at low speeds. Furthermore, it will not run backward. For these reasons, the ordinary steam engine is used where low speed and back-and-forth movements are needed.

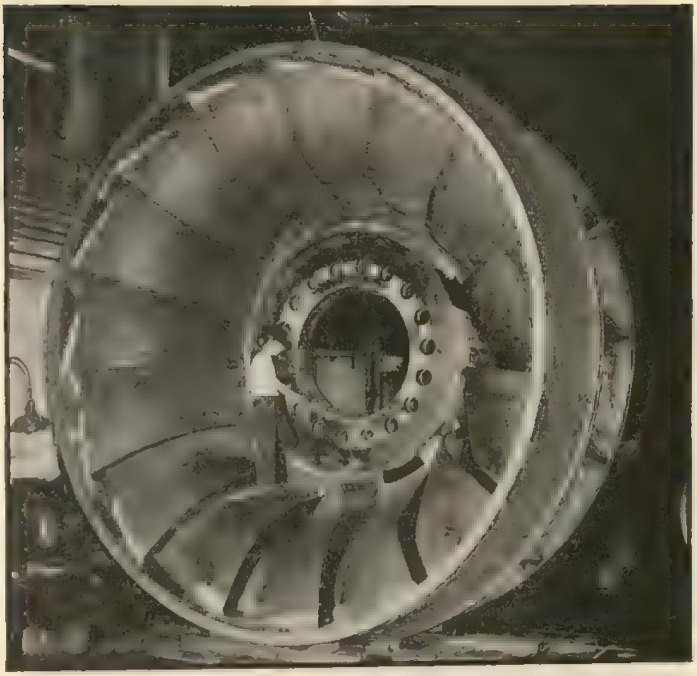
Other turbines, built somewhat like the steam turbine but with vanes (called buckets or blades), make use of the energy of falling water. The Francis wheel, a kind of turbine, has blades placed in its rim (Fig. 273). It is used where water falls a considerable distance with great force. To make water in rivers fall with sufficient energy to operate water turbines, dams are built to raise the water level. That is why at the base of most large dams you will find plants where huge dynamos, machines which produce electricity, are turned by the energy of falling water.

GASOLINE AND DIESEL ENGINES

You have learned that liquid fuels such as gasoline and alcohol vaporize easily; that is, they form gases even at low temperatures. These gases when mixed with the proper amount of air are very explosive mixtures.

It is hard to say just who should receive the credit for the invention of an engine that would make use of the energy caused by the explosion of gasoline vapor. Certainly men had thought about it ever since the drilling of the first oil well. A German engineer named Nikolaus Otto is in the records as having designed the first internal-combustion engine in 1886.

An internal-combustion engine is one in which the fuel burns inside the engine to produce power. The gasoline and Diesel engines are internal-combustion engines. On the other hand, the steam engine and turbine are external-combustion engines. Their fuel is burned outside the engine.



273
An example of one of the huge 165,000-horsepower turbine runners (a Francis wheel) in a shop of the Newport News Shipbuilding and Drydock Company. (Newport News Shipbuilding and Drydock Co.)

HOW DOES A GASOLINE ENGINE WORK?

The modern gasoline engine is one of the finest engines for the production of power. These engines are built in banks of four, six, and eight cylinders for automobiles and trucks. In airplanes there are banks of many more cylinders. However, each cylinder does the same kind of work. If you understand how one cylinder works then you will understand how large engines of many cylinders produce power.

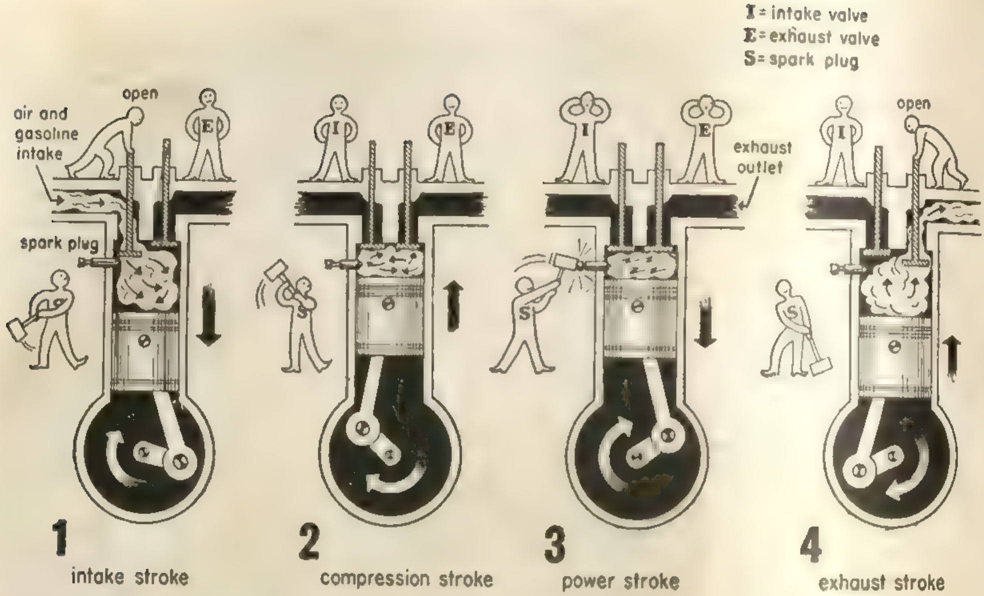
There are thousands of one-cylinder gasoline engines in use for sawing wood, for hand cultivating and plowing, and and for cutting grass. All of them have these parts (Fig. 274).

1. A cylinder
2. A piston which is tightly fitted into the cylinder
3. Valves to admit a mixture of gasoline and air and to let out waste or exhaust gases
4. A spark plug whose spark explodes the mixture of gasoline and air
5. A timing device to move the valves and bring the spark to the cylinder at just the right time
6. A rod from the piston which connects with the shaft of the engine
7. A flywheel
8. Oil to lubricate the moving parts

THE STROKES OF A GASOLINE ENGINE

The strokes of a gasoline engine give it power. But what are strokes? In the steam engine the piston moves back and forth in the cylinder. Each movement is a stroke, forced by the entering steam. In the gasoline engine, strokes are forced by the explosion of gasoline. Here is the way it works (Fig. 274).

1. *The intake stroke.* The piston moves downward in the cylinder, letting in a mixture of gasoline vapor and air. At this time the intake valve in the cylinder is opened. It's just like your bicycle pump, in a way. Instead of pushing downward, you draw the handle upward on the intake stroke and you



274 *The four strokes of a gasoline engine.*

make a partial vacuum in the pump. Air rushes in through a valve to fill this vacuum and then you push downward to force the air into the tire.

2. *The compression stroke.* Unlike your bicycle pump, the piston moves *upward* against the mixture of gasoline and air. Both intake and exhaust valves are now closed, so no gas can escape (Fig. 274). This movement of the piston pushes the mixture of gas and air into a small space—thus compressing it. This pressure against the gas mixture causes it to become extremely hot. The tight-fitting piston keeps the compressed gas from escaping.

Just as the piston reaches the end of the compression stroke, the mixture of gasoline and air is exploded.

3. *The power stroke.* Through the points of the spark plug comes the electric spark (Fig. 274). Immediately the hot mixture of gasoline and air explodes. The hot gases expand and force the piston downward. This explosion gives the gasoline engine its power.

A connecting rod from the piston to the crankshaft causes the crankshaft to turn (Fig. 274). A heavy flywheel attached to the crankshaft turns also. The movement of the flywheel brings the piston up into the cylinder again.

4. *The exhaust stroke.* As the piston moves upward, the exhaust valve opens. The rising piston pushes out the gases that cause the power stroke. Every trace of the burned mixture, except carbon, is pushed out of the exhaust pipe. When the piston reaches the end of its exhaust stroke and starts downward again, the intake valve opens on the intake stroke. Thus the strokes of the gasoline engine are continuous. If the strokes are not continuous, the engine may fail to work. Now turn your attention again to Fig. 274. Can you describe the strokes of the engine, the *intake*, *compression*, *power*, and *exhaust* strokes?

Nearly four-fifths of all power used in the United States comes from internal-combustion engines in automobiles,

trucks, trains, busses, ships, submarines, tractors, bulldozers, and small power plants. But for heavy work and long-continued power the Diesel internal-combustion engine is now being used.

THE DIESEL ENGINE

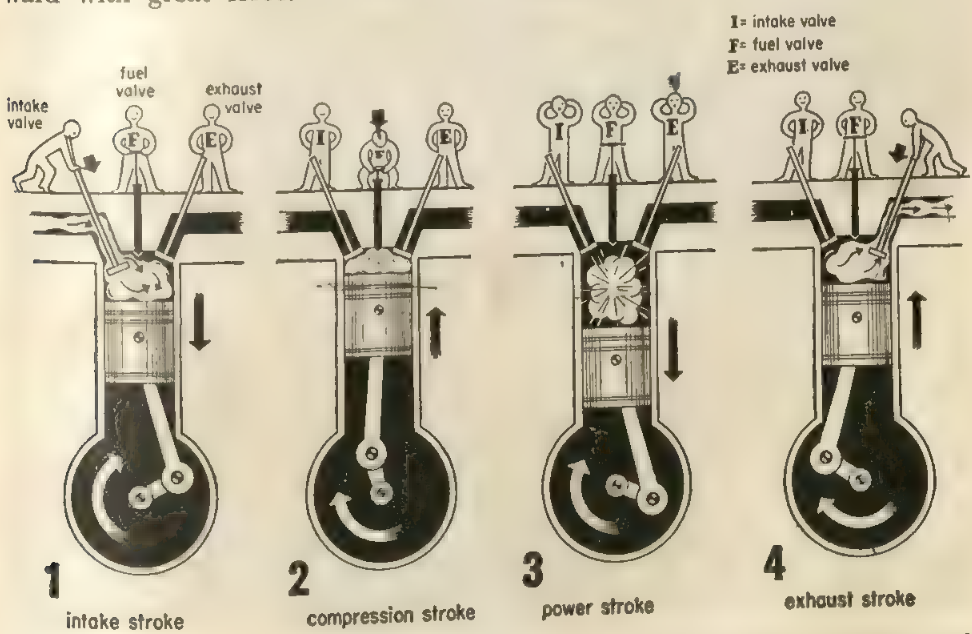
The Diesel engine is really a modification of the four-stroke gasoline engine. It is different only in these ways (Fig. 275).

1. The intake stroke admits *air only* through an intake valve.

2. The tight-fitting piston, moving upward in a long cylinder compresses this air in such a small space that great heat is generated. (This heat is far above the kindling temperature of heavy fuels.)

3. Just at this point fuel oil under heavy pressure is sprayed into the cylinder. The compressed air is so hot that the mixture of fuel oil and air explodes. This explosion forces the piston downward with great force. On the next stroke the upward movement of the piston pushes out the burned gases through an exhaust valve. Then the cycles are repeated again as in the gasoline engine.

In pulling heavy loads the Diesel engine is more efficient than the gasoline engine because it can get more heat from a lower grade of fuel. However, if the gasoline engine compressed its mixture of gasoline and air as much as the Diesel engine compresses just air, the mixture would explode before the piston reached the end of its compression stroke. Diesel engines are heavy engines (Fig. 276). Because of the long compression stroke, they need the strength of a thick cylinder wall. A gasoline engine of the same power is lighter and is more useful therefore in automobiles and airplanes. Diesel engines are finding special use in locomotives hauling modern trains. Look about you if you live near a rail center and note the Diesel locomotives.



275 *The four strokes of a Diesel engine. A spray of oil at the end of the compression stroke explodes and gives this engine its power.*

HORSEPOWER AND YOU

The term "horsepower" was first used by James Watt when he was trying to sell his steam engine to mine owners who were then using horses to raise coal from mines. He figured it this way: "My engine can do the work of several horses in the same length of time. But how can I measure the power of my engine?" Then, by careful measurement, he figured that a strong horse could lift on pulleys a weight of 33,000 pounds the distance of one foot in one minute. If the horse could keep on doing that lifting all day long, it would mean that an average of 33,000 foot-pounds (33,000 pounds × 1 foot) of work would be done each minute of the day, or in each second, 550 foot-pounds of work.

Of course, a horse could not work at that speed all day long. But James Watt's engine could. He told the mine owners that the power of his engine was equal to the power of a certain number of horses. And he sold his engine with this guaranteed power.

YOUR "HORSEPOWER"

As a measurement of power today, the term "horsepower" is generally used. Here's how you can find out what your horsepower is. You may weigh 100 pounds. If a stop watch is used, or a careful count made on the second hand of an ordinary watch, you can be timed running up a flight of stairs. Suppose the height you run up is 20 feet and you make it in just nine seconds by extra exertion and by taking two stairs at a time. You have raised your own weight 20 feet in nine seconds. This is how you figure it:

276 *One of the world's largest Diesel bulldozers in action, moving tons of rocks and earth. Would you like to drive it? (Allis-Chalmers Co.)*

Height of stairs: 20 feet
Your weight: 100 pounds
Time: 9 seconds

You have done 20 × 100 or 2,000 foot-pounds of work in 9 seconds. Two thousand foot-pounds divided by 9 (seconds) = 222.2 foot-pounds of work done in one second. One horsepower is 550 foot-pounds of work per second. The 222.2 pounds of work you produce in one second is close to one-half of 550 foot-pounds of work in one second (which is one horsepower). You have produced by your own energy almost one-half horsepower (Fig. 277).

You could not keep that up all day long. But engines can, and they produce a definite amount of horsepower continuously to furnish the needs of industry and transportation.

COST OF POWER

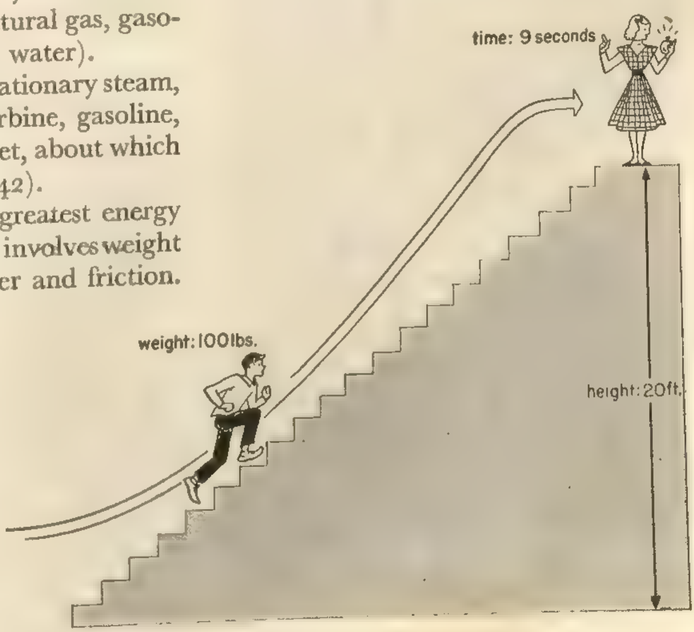
Today, the problem is to produce power as cheaply as possible. But the cost of horsepower produced depends upon many things. Here are a few:

1. The kind and quality of the source of power (wood, coal, natural gas, gasoline, fuel oil, wind, and water).
2. The engine used (stationary steam, steam turbine, water turbine, gasoline, Diesel, or jet and turbo-jet, about which you will read on page 442).
3. Ability to get the greatest energy per pound of fuel, which involves weight of engine per horsepower and friction.

Only a very small percentage of our nation's energy supplies have been tapped. This is particularly true of water power. During the last 25 years great dams have been built—Hoover, Grand Coulee, those in the Tennessee Valley, to mention a few. They harness the energy of rivers and produce power by generating electricity. Much remains to be done in controlling tides and flood waters, and in the building of dams to make the power of electrical energy a greater contribution to the life of our nation. More horsepower from the cheapest source that can be had will enhance our nation's wealth. At present, power from electricity is supplanting other forms of energy in the world's work.

ENRICHMENT BY ELECTRICITY

It has been calculated that the electricity available today in most homes gives you the equivalent of .1 to .5 of a horsepower working for you eight hours a day. This is equal to the work of one to five men. A man doing light work



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In running to the top of the stairs this young man is producing about one-half horsepower.

eight hours a day generates, on the average, about one-tenth of a horsepower. To put it another way, the amount of electricity you use to light or heat your home, to use the phone or radio, to iron your clothes, etc., is equal to .1 to .5 horsepower or the work of one to five men. This is a modest estimate and does not include all the uses of electricity in your life.

Because of electricity alone, you are richer than most men living in the year 1700. For most of these men did not have the powerful servant Electricity working for them. Would you like to know what electicity is, how it works, and how it produces power? Then read the next chapter on "Harnessing the Electron."

GOING FURTHER

1 *Kindling temperatures.* Place on asbestos mats, a match, a piece of paper, a small block of wood, and a chunk of soft coal. Light a Bunsen burner and direct its flame on each article until each one catches fire, that is, until you notice the articles give off light and heat. Make a note of the time required for each article to ignite. Make a list of them in order of their kindling temperatures.

2 *Power of steam.* Fill a test tube one-quarter full of water. Cover the outside of a cork stopper with vaseline and insert it into the mouth of the test tube. Holding the test tube with a test-tube holder, with the corked end pointed away from you, bring the bottom of the tube into the flame of a Bunsen burner. When the water starts to boil, what happens? What do you conclude as to the power of steam? Has it sufficient force to push a piston in the cylinder of a steam engine?

3 *Model turbine.* Insert into a one-hole stopper a glass tube that has been narrowed down at one end. Insert the stopper into the mouth of a flask one-quarter full of water. With a pair of tin-snips make a series of cuts about 1½ inches deep and 1 inch apart on the circumference of the cover of a tin can that has no lip. With a pair of pliers, twist the notched pieces of tin so that they have somewhat the appearance of the blades of a windmill. Pierce the center of the cover with a nail. Wind a short length of string around the nail on each side of the cover so that the cover will turn on the nail easily yet not move along the nail. Now attach the nail with cover and the flask to a ring stand.

Heat the flask. The force of the steam coming from the narrow end of the glass tube strikes the tin blades of the cover and the cover turns on the nail. What does this show you concerning the power of steam to whirl the blades of a turbine?

4 *Words are ideas.* Can you use these words in a sentence which will give their meaning? Use the glossary.

kindling temperature	internal-combustion engine
safety valve	Pelton wheel
piston	spark plug
steam engine	intake stroke
cylinder	compression stroke
flywheel	power stroke
gasoline engine	exhaust stroke
Diesel engine	horsepower
Industrial Revolution	
turbine	

5 *Put on your thinking cap.*

1. Why is steam such a good source of power?

2. What would you use to ignite
(*a*) a wood fire
(*b*) a coal fire
(*c*) gasoline vapor and air in a gasoline engine

3. In what ways would our civilization have suffered if the steam engine had not been invented?

4. Which engine would you use—stationary steam, steam turbine, water turbine, gasoline, Diesel—for the following operations:

(*a*) The generation of electricity at the foot of large dams

(*b*) Pumping water into the mains of a city

(c) Operating a 20-ton bulldozer

(d) Sawing wood with a power saw

5. A man weighing 160 pounds and carrying a 5-pound bag of sugar ran up a flight of stairs leading to a floor above. The vertical distance was 10 feet and his time was 6 seconds. Which of the following numbers represents the horsepower he produced: $3\frac{1}{2}$; 1; $\frac{1}{2}$; $\frac{3}{4}$?

6 *Test yourself.* In your notebook, complete the following sentences with an accurate word or phrase. Do not mark this book.

1. Water, when changing into steam, expands ...... times its volume.

2. The temperature at which a substance takes fire and continues to burn is called the ...... temperature.

3. A ...... valve prevents an unsafe steam pressure from building up in the boiler of a steam engine.

4. The steam ...... is used where a steam engine of light weight and high efficiency is required.

5. The stroke of the piston of the gasoline engine which expels the waste gases of the explosion is called the ...... stroke.

6. The stroke where the piston gives power to rotate the crankshaft and flywheel is called the ...... stroke.

7. The standard unit for measuring power is the ....

7 *Adding to your library.*

1. *Power from Start to Finish* by Franklin M. Rich and Claire Rich, Thomas Y. Crowell Co., 1941. This book traces power from the first source—the sun—to power for our modern factories.

2. *Science Looks Ahead* by A. M. Low, Oxford University Press, 1942. The section entitled "Power" discusses power to be derived from water, steam, coal, and oil. Special mention is made of Diesel engines.

3. *The Modern Wonder Book of Trains and Railroading* by Norman Carlisle, John C. Winston Co., 1946. This story of railroading includes science in the railroad business, unusual trains, and modern railroading.

4. *It Works Like This* by Burr Leyson, Dutton, 1942. This book contains excellent explanations of the Diesel engine and the steam engine.

CHAPTER 23

HARNESSING THE ELECTRON

Why should a doctor be interested in hooking up frogs' legs, of all things, to an electric current? Let's visit the laboratory of Luigi Galvani, an Italian doctor in the year 1790, to explore this odd matter.

Galvani had stretched out a pair of frog's legs on the bench in front of him. They were the legs of an exceedingly large and powerful frog, and they had looked so appetizing to Galvani's wife in the market place that she had purchased them for her husband's dinner.

That didn't matter to Galvani. He wasn't going to hurt the meat; he was just going to do another experiment to help him write a book about the reactions of animal flesh to different kinds of metals.

Galvani took up a strip of iron and a strip of copper and touched the muscles of the frog's legs with the two metals. Immediately the legs started to twitch. He moved the metals over to another place. Again the legs twitched as if they were alive. Meanwhile Galvani, like all good scientists, took notes.

Galvani's notes went something like this: "The muscles and nerves of a frog are affected by a mysterious force that is in the copper and iron strips. What that force is I do not know." Today a scientist would write: "When two different metals are placed on the moist muscles of a frog, a tiny electric current is produced that causes the muscles to twitch." The two conclusions are not so very different after all, are they? In modern terms the force is called "an electric current." That is just what Galvani's tiny invisible force was.

In this chapter you will learn that electricity is the movement or flow of electrons from one place to another. There is a definite relationship between this flow of electrons and magnetism, a relationship which is the source of all electrical power. You will come to understand how we make use of electricity and why it is one of our greatest servants today.

STATIC ELECTRICITY

Amber is a hard, yellow substance. In ancient Greece people picked it up on the seashore and cut it into ornaments. It remained for Thales (thā'lēz), a Greek philosopher who lived about

2,500 years ago, to discover that amber, or "electra" as the Greeks called it, has a mysterious power. That is, if rubbed briskly with a cloth, it attracts small particles such as pieces of straw and dried leaves. However, Thales had no satisfactory explanation for this attraction and this property of amber remained a mystery for centuries.

ELECTRICITY GETS ITS NAME

About 2,150 years after Thales, an English physician named William Gilbert discovered that not only amber but also other materials such as wax, sulfur, mica, and glass have the power of attracting light articles when rubbed. Gilbert was the first to give this power a name. He called it "electricity" from the Greek word "electra." But like Thales, he had no satisfactory explanation. He and other scientists believed that these materials when rubbed gave off invisible heated rays and that when these rays were cooled by the surrounding air, they rushed back to their source, carrying with them light objects they picked up along the way.

However, this explanation is far from the truth. Let's see what modern scientists understand about static electricity.

POSITIVE AND NEGATIVE ELECTRICITY

When an object contains static electricity, it is said to be electrically charged. The electric charge on the object may be *positive* or *negative*. Let us see how this comes about. In Chapter 12 you learned that atoms are made up of particles such as electrons, protons, and neutrons. The protons and neutrons are inside the nucleus; the electrons are outside. You also learned that electrons are always negatively charged and protons are always positively charged.

In an atom the number of positive protons and negative electrons is the same. Therefore, the atom is electrically balanced. In other words, an atom has the same number of positive and negative charges.

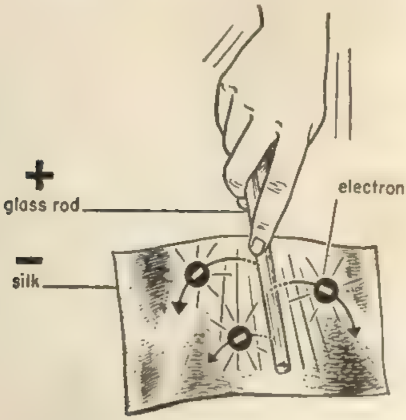
The electrons in atoms and molecules of some substances can be disturbed easily by friction, or rubbing. They may be actually transferred from one article to another. For example, when you rub a glass rod with a silk cloth, some of the electrons from the rod are transferred to the cloth. This leaves the glass rod with more positive charges than negative charges. The rod is said, therefore, to be charged with positive electricity. The cloth has received electrons (negative charges) from the glass rod. The cloth is said, therefore, to be charged with negative electricity (Fig. 278).

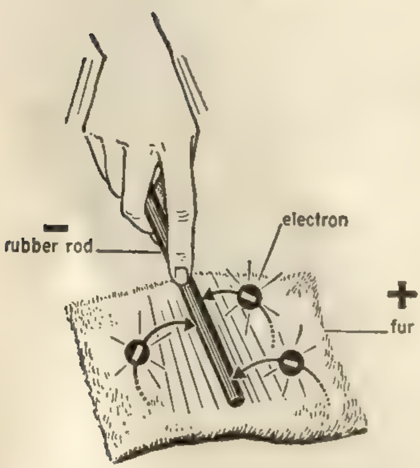
On the other hand, if a hard rubber rod is rubbed with a woolen cloth or a piece of fur, electrons from the cloth or fur are transferred to the rubber rod. In this instance the rubber rod, having received electrons, becomes negatively charged, and the wool cloth or fur, having lost electrons, is positively charged.

Whenever an object loses electrons its atoms become unbalanced. The atoms require a supply of electrons to regain their balance. They attract or draw electrons to themselves. Thus the object is said to be positively charged, as is the case with the glass rod. On the other hand, an object which has temporarily taken on more electrons than its own atoms require is negatively charged, as is the case with the rubber rod.

Here is an experiment that shows clearly these two different kinds of charges and how they act. Hang a pith ball from a ring stand by a silk

278 (Above) *When rubbed with a piece of silk, the glass rod loses electrons to the silk and becomes positively charged.* (Below) *When rubbed with a piece of fur, a rubber rod gains electrons from the fur, and becomes negatively charged.*





thread. (A pith ball is about the size of the end of your little finger and is made from the inner part, or pith, of the dried stem of a plant.) Rub a glass rod briskly with a piece of silk and touch the pith ball with the end of the rod (Fig. 279).

Here is what happens. When you rub the glass rod with the silk cloth, the rod loses electrons to the cloth. The rod needs these electrons to become electrically balanced or neutral. It draws some of these electrons from the pith ball. The pith ball clings to the glass rod while giving up those electrons. As it gives up its electrons, the pith ball becomes positively charged like the glass rod. It drops from the glass rod. When the glass rod is brought near the pith ball again, the pith ball is violently repelled. Since both rod and pith ball are positively charged, they both now need electrons, and neither one has ready electrons to give to the other.

Now give a rubber rod a negative charge by rubbing it briskly with wool or a piece of fur. Bring the end of the rubber rod close to the positively charged pith ball. The pith ball, positively charged (it lost electrons to the glass rod), is attracted to the rubber rod, which has a surplus of electrons. There it clings while getting electrons to restore its electrical balance—its electrons now are equal in number to its protons.

From experiments similar to these scientists have found (1) that friction between two different objects like glass and silk or rubber and fur produces a positive charge on one and a negative charge on the other, (2) that two objects with the same charge repel each other, and (3) that two objects with different charges attract each other. These conclusions may be expressed in a simple law: Like charges of electricity repel each other and unlike charges of electricity attract each other.

WHAT CAUSES ELECTRIC SPARKS?

The reason two objects with opposite charges of electricity attract each other is that one lacks electrons and the other has more electrons than it needs. Thus two objects with opposite charges tend to draw together and electrons may

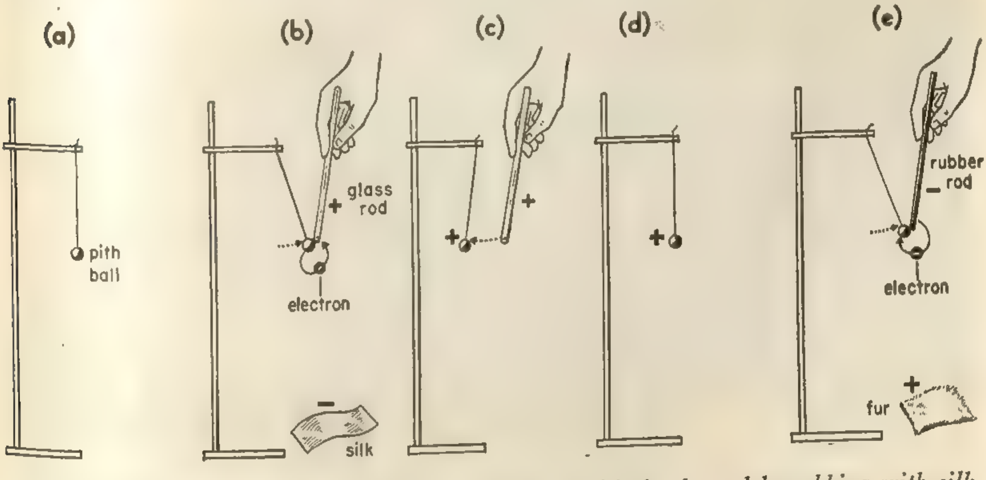
pass from the one which has more electrons to the other.

Ordinarily the air resists the passage of electrons but whenever any charge of static electricity is great enough, this flow of electrons may pass from one object to another through the air. That is, the flow of electrons breaks down the resistance of air to its passage. When this happens, an electric spark occurs that may be heard as well as seen.

If you were to rub a cat's fur in the dark when the air is dry and cold, you would notice sparks in the fur. Friction on the countless number of hairs builds up a great number of static electrical charges. These charges break down the resistance of the air and pass between the hairs in the form of electric sparks.

Electric sparks, caused by static electricity, are feared by people who work in coal mines or in factories where flour or other powdery products are made, and by drivers of gasoline trucks. Finely divided dust is an explosive substance when mixed with air. In fact, engines have been operated by dust explosions. In coal mines dust is often present in explosive quantities. Under these conditions, any source that might produce a spark by friction is carefully watched and controlled. In some gasoline trucks, the friction of the sloshing gasoline inside the tank builds up a large charge of electricity. The rubber tires, like the rubber coating around wire carrying electric current, insulate the truck body. That is, as insulators they prevent the electricity built up in the truck from passing into the earth. Next time you see a gasoline truck notice the chains attached to it. The chains drag along the ground as the truck rolls along, sending the flow of electrons built up in the truck into the earth.

Suppose there were no way to lead this charge into the earth. A spark from the nozzle of the hose which delivers the gasoline to an underground tank might cause a serious explosion or fire.



279 *At the left is a pith ball* (a). *A glass rod, positively charged by rubbing with silk, is brought near the pith ball* (b). *The pith ball with its loosely held electrons is attracted to the glass rod and gives up some of its electrons. It then becomes positively charged and is repelled by the rod* (c). *The pith ball remains positively charged* (d). *A rubber rod, negatively charged by rubbing with fur, now attracts the ball* (e).

280 *Experiments with man-made lightning in laboratories like the one shown above help engineers to build antennas and transmission lines that withstand lightning bolts in great storms.* (*Radio Corporation of America*)

LIGHTNING

Lightning breaks down the resistance of air between highly charged clouds and between clouds and the earth. Man-made generators have never equaled the display of electric power

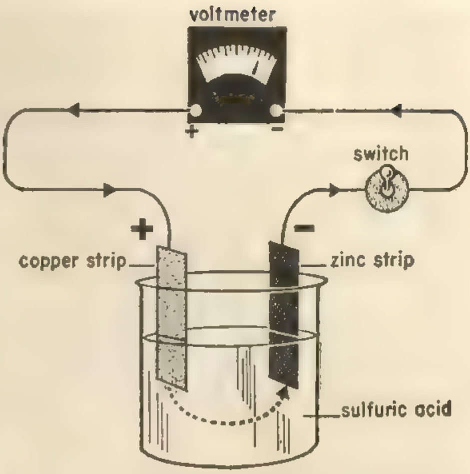
shown in a discharge of lightning. An electric charge is built up when rising air currents create friction in the moisture of the clouds above. Then air currents and clouds move up and down swiftly. Large charges of static electricity are generated. When there is a discharge of electrons from one cloud to another, a flash, jagged in appearance, breaks across the sky. Thunder rolls after the flash. When heavily charged clouds move close to the earth, some point on the earth transfers the electron charge into a bolt of lightning. The thunder is caused by the expansion of air during the heat of the lightning flash and by the rush of the surrounding air to fill the partial vacuum caused by the sudden expansion of the heated air.

Cameras have recorded bursts of lightning during heavy storms. The steel used in every skyscraper conducts lightning into the earth without damage to the building.

Lightning causes very little damage, considering the frequency of thunderstorms. Lightning rods on buildings pass the flow of electrons harmlessly into the earth. Lightning should not be feared provided you follow the simple rule outlined in the unit on weather. Lightning is just a display of static electricity on a huge scale. The gigantic flow of electrons which causes lightning has not yet been controlled by man. But every day in your home and school you control a flow of electrons (Fig. 280).

CONTROLLING ELECTRONS

Have you ever considered the importance of the switch on your bicycle headlight, your flashlight, or in your home? Switches are useful things. They control a flow of electrons. But the



281 *The voltmeter shows that an electric current is produced by a simple voltaic cell. What is the source of the electron flow?*

electrons must have a source that produces them. What is this source? Why does the pushing of a switch heat a flatiron or light your home?

VOLTA'S CELL

In 1796, Alessandro Volta made a great discovery. He built an arrangement of zinc and copper disks, separated by strips of leather soaked in salt. We now know that when he connected the zinc disks and the copper disks, electricity flowed through the wire leading from the disks of zinc and copper. The apparatus is called a voltaic pile. This was the first method by which electricity was made to flow through wires.

You can make a simple voltaic cell by placing a copper strip and a zinc strip in a solution of dilute sulfuric acid. You should connect the zinc and the copper strips to a switch and a voltmeter by means of an insulated copper wire as is shown in Fig. 281. A voltmeter measures the strength of the flow

of the electrons. When you press the switch, the needle of the voltmeter will move. This indicates that a flow of electrons is passing from the voltaic cell. When you release the switch, the flow stops and the voltmeter needle returns to its original position; that is, to 0.

The source of the flow of electrons in the voltaic cell is chemical action. The zinc and copper react in the presence of the sulfuric acid in such a way as to give off electrons. These electrons flow out in the complete circuit as electricity.

THE FLOW OF ELECTRIC CURRENT

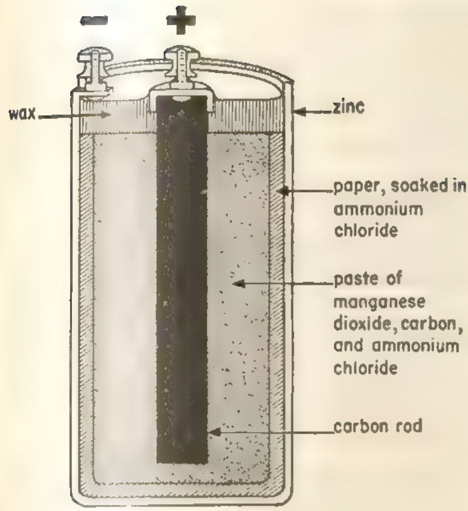
A complete electric circuit is necessary for electrons to flow. An electric circuit is made when electrons flow from a source producing electricity and back to the source. That is why you can light your room just by pressing a button that closes a switch. When you turn off the light, you open the switch and no electrons can pass the gap. That is also why in manufacturing plants and other places, wherever electricity is used, a complete electric circuit can be made merely by closing a switch. This action allows electrons to flow and do work in lighting, heating, and generating power. When the switch is opened, electric light, heat, or power stops immediately.

Have you ever had a choice of two guesses and made the wrong guess? Although Benjamin Franklin was one of our greatest scientists, he made a wrong guess about the direction in which an electric current flows outside a cell. He knew there were two poles or centers, one positive and the other negative, between which a flow of electrons could pass. He guessed that this passage was from the positive to the negative. Since most people accept this today, it would cause more confusion to change it than to let it stand. However, when you see a reference to a current of electricity flowing from a positive pole to a negative pole outside a cell, it really is the reverse. The flow of electrons actually flows in the opposite direction—from the negative pole to the positive (Fig. 281). And you know the reason: Electric current is a flow of electrons. The flow has to start from the point where there is an oversupply of them, at the negative pole.

THE DRY CELL

The dry cell is today the most familiar source of electric energy. Except in storage batteries, wet cells like the original voltaic cell are seldom used. But even the dry cell in your flashlight is not really dry. It contains the following substances: a cylindrical zinc container that acts as the negative pole or plate, a carbon rod that acts as the positive pole. Around the inside of the container is a lining of absorbent paper soaked in a solution of ammonium chloride. Between this paper and the carbon rod there is a paste of manganese dioxide, finely divided carbon, and ammonium chloride (Fig. 282). The dry cell acts like the voltaic cell. The zinc container is the negative plate and the carbon pole the positive plate. The manganese dioxide reacts with hydrogen gas that is released by chemical action on the zinc. If not removed by the manganese dioxide, the hydrogen would act as a blanket over the carbon pole and the flow of electrons would decrease. The ammonium chloride acts as the sulfuric acid did in the simple voltaic cell. It transfers electrons from one pole to the other.

When a dry cell is used for a long time it grows weak because more hydrogen is generated than can be taken care of by the manganese dioxide. Also, the



282 *This is what you would see if you cut open a dry cell lengthwise.*

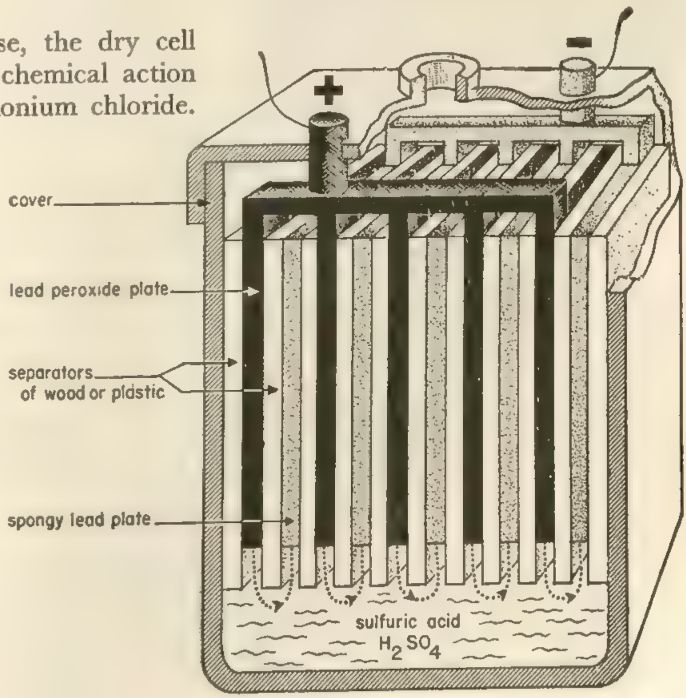
ammonium chloride is being used up. After a rest, the cell may regain some of its ability to produce a flow of electrons because the manganese dioxide has had time to react with the excess hydrogen, thus removing it from around the carbon pole.

But after further use, the dry cell goes "dead," that is, chemical action has used up the ammonium chloride. Then no more electrons are transferred from the zinc plate to the carbon pole.

THE STORAGE BATTERY

If it were not for storage batteries, automobiles and trucks would not have electric lights and starters. These batteries furnish a large amount of electric current by the chemical action of sulfuric acid upon two different kinds of plates. One of these plates is made up of a kind of spongy lead and the other plate is made up of lead peroxide. About 50 of these plates are placed in three separate cells of the battery but the plates are separated by wood or plastic separators. However, all the spongy lead plates, the negative plates in each cell, are joined together. So are all the positive lead peroxide plates. When a complete circuit is made, there is a large current or flow of electrons from a battery of this type (Fig. 283).

After a while chemical action in the storage battery changes both the spongy



283
Here is a cross section of a storage battery, such as is used in an automobile to operate the starter and light the headlights. How can this battery be recharged?

lead plates and the lead peroxide plates to a different kind of plate. This new kind of plate is made up of a substance called lead sulfate. The current then gradually ceases to flow. You have learned that in voltaic cells and the dry cell the plates or poles must be of different materials. Otherwise a flow of electrons will not occur. The storage battery must also have different kinds of plates. When a good part of each kind of plate has been changed to lead sulfate, the battery is called "dead."

To keep the storage battery from going dead we must send a flow of electrons into it from some other source. This new electron flow enters the battery in a direction opposite to that of the current coming from the battery. This current that we now send into the battery reverses the chemical action that has made both kinds of plates alike. This is the sort of thing which happens in an automobile. While you are drawing current from your battery to operate your engine and lights, your engine operates a device which generates electricity. This is sent back into your battery to keep it "charged."

MAGNETISM AND ELECTRICITY

Probably no one has ever been more surprised than the first person who noticed that a certain kind of rock could attract metal articles. Long ago, this magnetic rock or lodestone was tried as a cure for diseases and even toothaches!

THE FIRST MAGNET

Lodestone or magnetic oxide of iron occurs naturally in many sections of the world. It is this rock that was used in magnetizing needles in the first compasses. Today we have magnets made of steel or special alloys. These magnets are hundreds of times more powerful than lodestone. And with electricity we can make even more powerful magnets.

HOW MAGNETS ACT

Place a penny, a nail, a brass screw, a piece of glass, a gold ring, a piece of paper, and a paper clip on a table. Bring a bar magnet close to each one. (A bar magnet is a straight piece of magnetized metal, not U-shaped.) Which articles are attracted? Now bend a paper clip in the form of a hook or cradle. Support a bar magnet upon this cradle and hang the cradle from a support. Let the bar magnet come to rest. Does it point north and south?

You have now made a crude compass. Why does a compass tell direction? It tells direction because the magnetized bar or needle always points north and south.

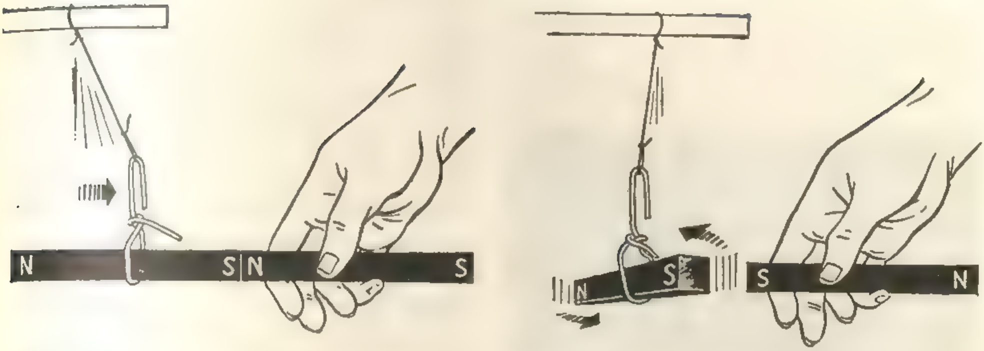
Now bring one end of another bar magnet near the end of the magnet in the cradle that points north. Is there any attraction between the two (Fig. 284)? Now bring the same end of the bar magnet near the other end of the magnet in the cradle that points north. Is there any attraction between the two? Now bring the same end of the magnet near the other end of the magnet that points south. What happens?

By these experiments you have shown that magnets have certain properties:

1. Magnets attract only certain substances, such as iron or steel.

2. When allowed to swing freely, one end of a straight magnet will point north and the other end will point south. In other words, a magnet has a north-seeking pole at one end and a south-seeking pole at the other end.

3. Unlike poles of magnets attract each other; like poles repel each other.



284 *Which poles of a bar magnet attract each other? Which poles repel?*

MAGNETIC INDUCTION

As you remember from your reading in Chapter 10, a cyclotron has extremely powerful magnets. When the cyclotron is operating no one should wear a watch in the building where it is housed. The reason is that the magnets of the cyclotron are so powerful that they will magnetize iron or steel articles even at a distance. You can imagine what that would do to a watch! With every part of the watch a separate magnet with moving poles, now attracting, now repelling each other, it could not keep time.

By means of magnetic induction, you too can make a magnet. Take a steel darning needle and stroke it from the middle to one end with the north pole of a bar magnet. Then cut a piece of a paper drinking straw the same length as the needle. Halve the straw vertically with a sharp knife. Mark one end of one of the halves S and the other end N. Place the needle in the straw with the end you stroked on the S end of the straw. The halved straw is now like a boat, carrying the needle. Place the straw boat in a saucer of water. Now bring the south pole of the bar magnet near the stroked end of the needle. The needle is repulsed and the boat swings around. This shows that you have induced a south pole in this end of the needle by stroking it with the north pole of the magnet. Has a north pole been induced in the other end of the needle at the same time? How would you prove this?

Now let the darning needle on the floating straw come to rest and watch which way it points. Have you made a compass as well as a magnet? This experiment has shown:

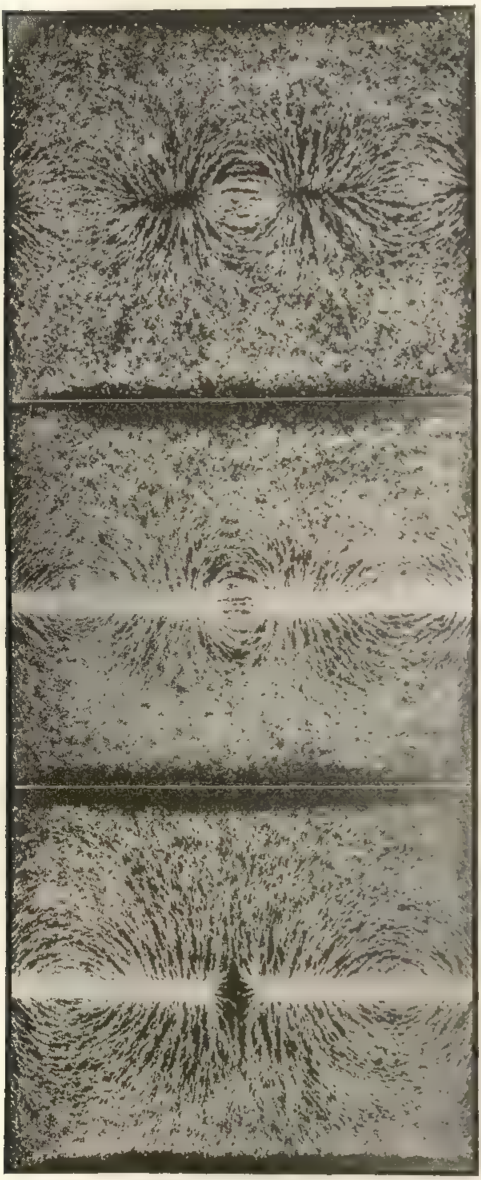
1. That a magnet can make another magnet.
2. That the magnet produced also has north and south poles.
3. That the magnet produced can act as a compass.

WHAT IS MAGNETISM?

Although there are various theories, no one knows exactly what magnetism is or exactly how it is induced into other metals. Since the invention of the first compass, men have known that the earth possessed a mysterious force that caused the compass needle to come to rest in one position. Today we know the earth itself is a large magnet.

The north and south magnetic poles of the earth are located at some distance from the north and south geographic poles. The north- and south-seeking poles of a compass, therefore, do not

point to the geographic north or south poles but to these magnetic poles. Navigators of airplanes and ships must take this variation of the compass needle into account when plotting their positions.



285 (Top) *Lines of force around and through a bar magnet.* (Center) *Attraction of unlike poles. Notice combining lines of force.* (Bottom) *Repulsion of like poles. Notice repelling lines of force.*

It is also known that some magnetized metals have stronger magnetic effects than others. The magnetism is also held for varying periods of time. Soft iron magnetizes easily and loses its magnetism just as easily. Steel magnetizes with greater difficulty but makes a strong magnet that holds its strength for a long time. An alloy called alnico, consisting mainly of nickel and cobalt, magnetizes with difficulty. However, it makes a very strong magnet that holds its strength longer than any other material.

PICTURING MAGNETISM

Even though we don't know exactly what magnetism is, it is possible to picture it. Place a glass plate or cardboard square over a bar magnet. Shake some iron filings over the surface of the plate. Tap the plate gently with your finger. The iron filings take on a certain pattern (Fig. 285). Now remove the plate. Move the north pole of another bar magnet about one inch away from the south pole of the first. Place another glass plate over both poles, sprinkle more iron filings over the plate and tap as before. Examine the pattern (Fig. 285). Repeat, but this time with a glass plate over two like poles. Again examine the pattern (Fig. 285).

You have demonstrated by these experiments the following:

1. That magnetism shows itself in a pattern called *lines of force.* These lines shown by the pattern of iron filings appear to extend in all directions—all around and through—a magnet from the south to the north pole. The strength of a magnet depends upon the width or "field" of these lines of force.

2. That attraction between two un-

like poles is accompanied by what appears to be a combining or union of the lines of force surrounding both poles.

3. That repulsion between two like poles is accompanied by what appears to be the pushing away or repulsion of the lines of force surrounding both poles.

MAGNETISM MADE BY ELECTRICITY

In the year 1819 Hans Oersted (ûr′stĕd), a Danish scientist, made an exciting discovery. He found when he held a wire carrying an electric current over a compass that the compass needle would turn away from its north-seeking position. He learned that any wire carrying a current of electricity has a magnetic field around it.

Only two years later, in 1820, a French scientist, André Ampère (ăm′-pẽr′), found that a coil of wire carrying an electric current acted the same way as a magnet; that is, it had north and south poles. Later discoveries showed that a bar of soft iron placed in the center of the coil of wire would greatly increase the strength of this magnet. Today, industry uses huge electric magnets based on Ampère's discovery to lift and carry tons of steel from one place to another.

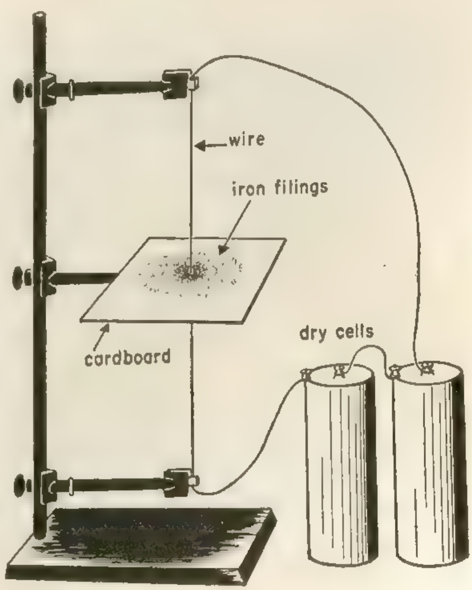
You can easily perform both Oersted's and Ampère's experiments. Puncture a hole through the center of a cardboard square and pass a long length of wire through the hole. Clamp about two feet of the wire in a vertical position to a ringstand. The cardboard square is in the center of the wire (Fig. 286). Attach the ends of the wire to the two terminals of a dry cell. Lightly sprinkle some iron filings on the cardboard around the wire and tap the cardboard gently. What position do the iron filings take (Fig. 286)? How does this experiment help you understand Oersted's discovery?

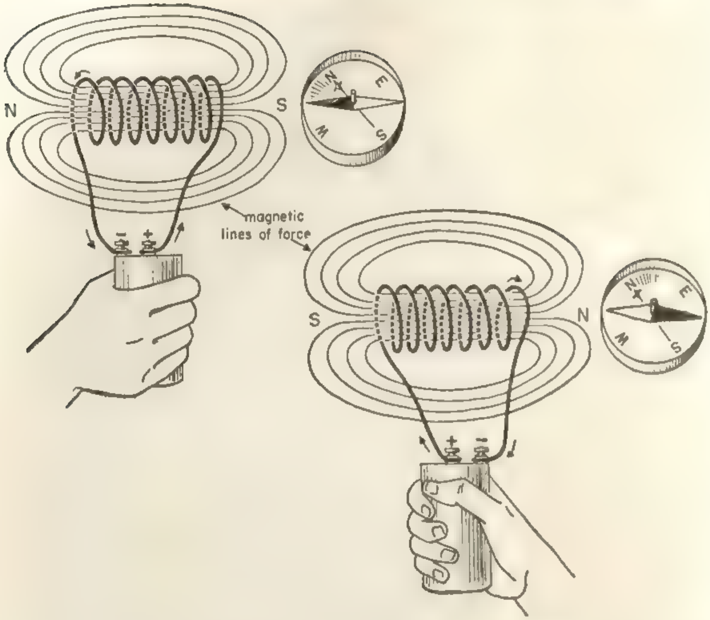
Now disconnect the wire from the battery and remove the cardboard square. Wind about two feet of the wire around a pencil to make a coil. Again attach the ends of the wire to the terminals of the dry cell. Bring one end of the coil near the north pole of a compass. Is there attraction or repulsion? Do the same with the other end of the coil (Fig. 287). You will find that a coil of wire carrying an electric current acts as a magnet with north and south poles.

MAKING AN ELECTROMAGNET

The coil of wire that you have just made is really a weak electromagnet when it carries an electric current. But how are strong electromagnets made—that is, those that are capable of lifting and moving tons of steel or iron? You can find out by doing a few simple experiments.

286 *Oersted's experiment. Does an electric current flowing through a wire produce magnetism?*





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Notice attraction and repulsion of the compass needle. Does a coil of wire with electricity flowing through it act like a bar magnet?

Sprinkle enough iron filings on a cardboard square to make a small pile. Take the coil of wire you have just made and attach the ends of the wire to the two terminals of the dry cell. Now touch the pile of filings with one end of the coil. You will find that some of the filings are attracted by the coil.

Pass a steel knitting needle or a similar piece of steel through the center of the coil and touch the filings as before. Now the steel knitting needle picks up some of the filings. The needle with its wire is an electromagnet, a magnet whose attraction for certain metals is due to electricity.

Insert an iron spike in place of the knitting needle. The thick iron spike picks up more of the filings than did the needle.

Attach another dry cell to the first by joining the center terminal (+) of one to the side terminal (−) of the other with a short piece of wire. Attach the ends of the coil around the spike to the two remaining terminals of the cells and touch the filings as before. The iron spike picks up more iron filings because a stronger current of electricity flows through the coil.

Now wind six feet of wire around the spike. Attach the ends to the dry cells and repeat as before. You will find that the spike picks up more filings when more coils of wire carrying an electric current are wound around it.

By now you have come to some understanding about how strong electromagnets are made. You have found:

1. That a strong magnet needs a heavy iron core (the iron spike).

2. That a greater electric current makes a stronger magnet.

3. That more turns of wire about the core make a stronger magnet.

A magnet that lifts tons of iron or steel must be constructed with a tremendous iron core with thousands of turns of wire carrying a powerful electric current.

ELECTRICITY FROM MAGNETISM

About a hundred years ago the son of a blacksmith, who never had any

of the advantages you have or even a portion of the knowledge you have today, became interested in science. At thirteen years of age this boy was apprenticed to a bookbinder. Luckily for him this position offered opportunities to read scientific books. He then applied for and received permission to work with the foremost scientists of England. Because of his discoveries we have today the knowledge to make electricity by using magnetism. This boy's name was Michael Faraday.

Here is what Michael Faraday discovered. His discovery came almost at the same time as that of an American scientist, Joseph Henry, although they worked entirely separately. Faraday wound two coils of wire around a soft iron core and connected just one of the coils to a battery (Fig. 289). The moment the connection was made, an electric current was induced in the second coil! And when the connection was broken, again a current was induced in the second coil—but this time it flowed in the opposite direction to the first! These slight currents Faraday measured by means of a delicate instrument called a *galvanometer* (găl′-vȧ nŏm′ê tẽr).

The explanation of Faraday's discovery is this:

1. The passage of an electric current through a coil of wire makes the coil a magnet.

2. This coil magnet sends out lines of force. Or we can say a magnetic field is formed the instant the switch is closed and a complete circuit is made (Fig. 289).

3. These lines of force "cut" through the second coil.

4. In cutting through the second coil, the lines of force induce a flow of electrons (an electric current) in the second coil.

In his later experiments Faraday confirmed these findings. He also discovered that when an electric conductor, that is, any metal wire or coil that conducts electricity easily, moves through a magnetic field, a current of electricity is induced in that conductor. Silver and copper are both excellent conductors, but silver is expensive. Therefore, copper is the metal most widely used as an electrical conductor.

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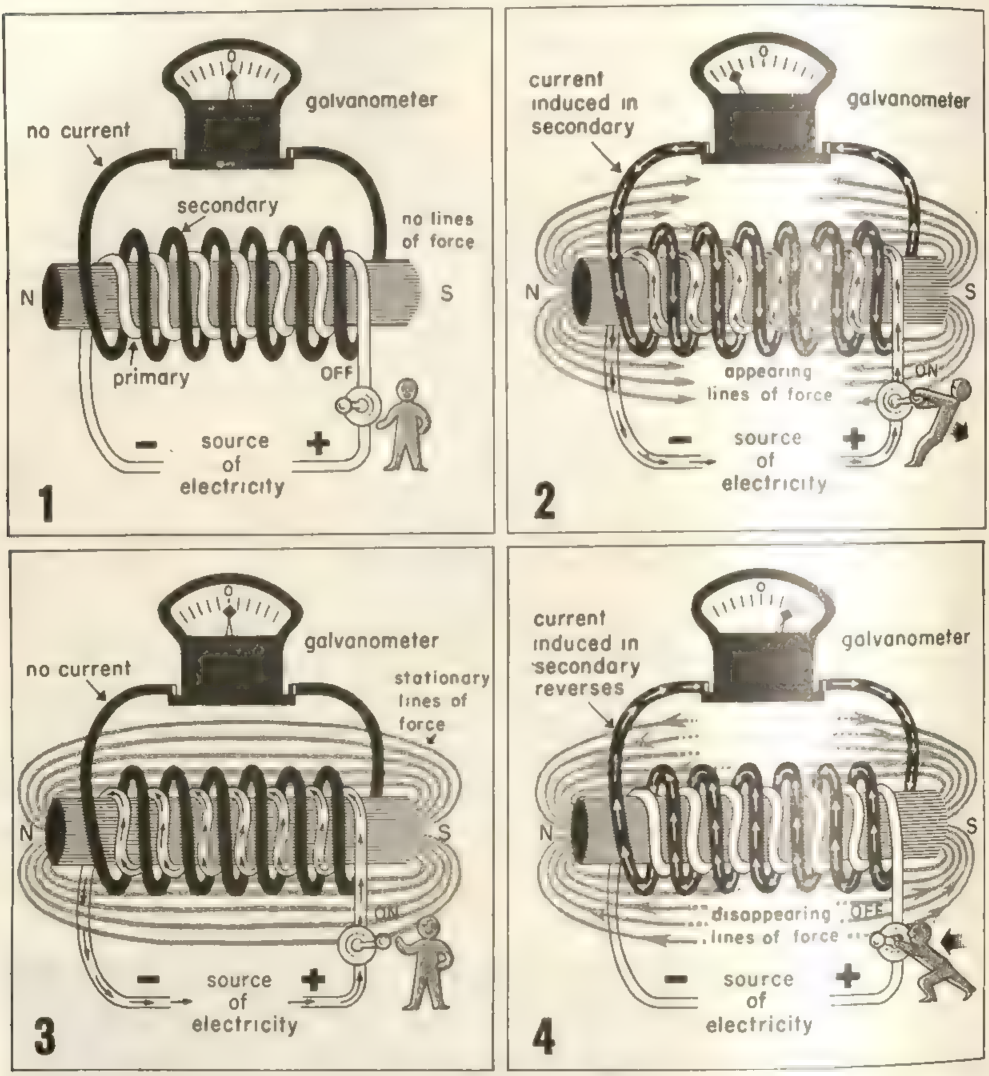
Do this experiment at school or at home. A spike with many turns of wire coiled around it can pick up nails. How can an electromagnet pick up tons of steel? (*Roger Horowitz*)



289 *In 1 the direct current is off. Therefore no current flows and there are no lines of force. In 2 the current is turned on. When the current flows in the primary, lines of force are created which cut through the secondary coil and induce a current there (going in the opposite direction from that in the primary). In 3 a steady direct current is flowing through the primary, and the magnetic lines of force are therefore stationary, that is, they do not move through the secondary coil. Why does the galvanometer needle point to zero? In 4 the switch is turned to "off" position, direct current ceases to flow through the primary, and the lines of force disappear. As they do so, they cut back through the secondary coil, inducing there an electric current that flows in the direction opposite to that in which it flowed in 2. Why does the galvanometer needle point to the right of zero?*

IN AN ELECTRIC POWER STATION

If you have ever visited an electric power station, you know that the energy of falling water or steam (from coal) is used for turning turbines. These turbines in turn whirl coils consisting of thousands of turns of copper wire through strong magnetic fields (produced by magnets). These coils are found in huge *generators* or *dynamos*.

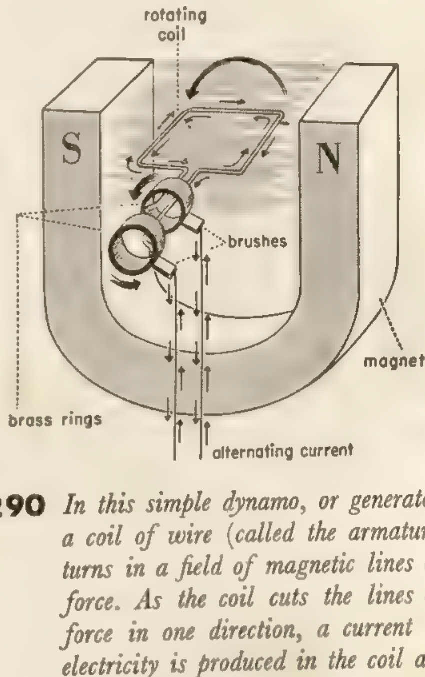
What is a dynamo? It consists, first, of an *armature*, the moving part which in the simple dynamo we are describing (Fig. 290) consists of one coil of wire. Second, there is a magnet between the poles of which the armature turns. This magnet produces a strong magnetic field (Fig. 290). As the armature is turned within the magnetic field, its movement cuts across the magnetic lines of force and produces a flow of electric current. To understand how electric generators or dynamos work, study the following diagram along with the text. In Fig. 290 you will notice:

1. The north and south poles of an electromagnet. This electromagnet is producing a strong magnetic field.

2. As the coil of wire, the armature, makes one complete turn in this magnetic field, an electric current flows. Since the loop of wire reverses itself as it turns in the magnetic field, the current flows first in one direction, then in the other direction; that is, it alternates in its flow. Because the current moves in alternating directions, it is called an *alternating current* or *A.C.*

3. To get this alternating current into the outside wire as the armature (the single coil of wire) turns, the ends of the armature are attached to two brass rings (Fig. 290). Steel brushes (made of replaceable, flexible steel wire) rubbing on these brass rings lead off the electric current to the galvanometer, the measuring instrument. Since the current alternates first in one direction, then the other, the needle of the galvanometer swings first in one direction and then in the other.

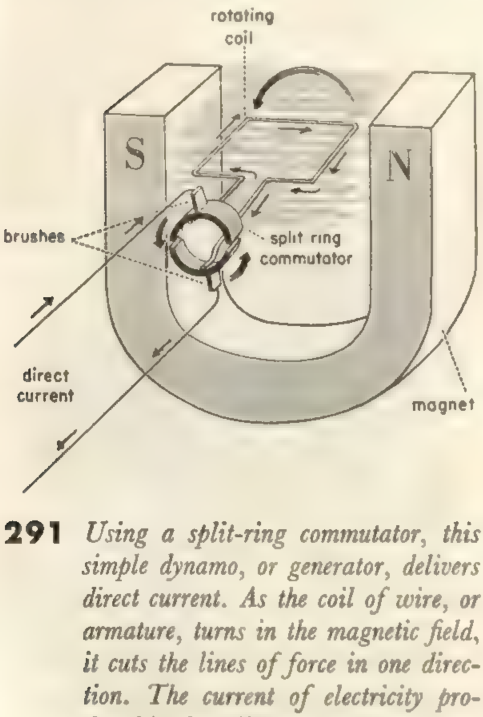
4. An alternating current can be changed to *direct current* or *D.C.* by using a *split-ring commutator*. You can see in Fig. 291 that a split-ring commutator is merely a ring which is split into two. In measuring direct current, the needle of the galvanometer remains steady since the current flows only in one direction. It does not alternate as in alternating current.



290 *In this simple dynamo, or generator, a coil of wire (called the armature) turns in a field of magnetic lines of force. As the coil cuts the lines of force in one direction, a current of electricity is produced in the coil and flows out through one of the brass rings. Next the coil cuts lines of force in another direction and a current of electricity flows out through the other brass ring in the opposite direction from the first flow. Because the current or flow of electricity alternates in direction, it is called alternating current, or A.C. Do you have alternating current in your home?*

To summarize how alternating and direct current electricity is produced by dynamos at an electric power station: Falling water or steam turns turbines which turn the armatures of huge generators. These armatures, huge coils of wire with iron cores, cut across magnetic fields of force to produce a current of electricity which is led off into wires.

The strength of the current produced depends upon the number of magnetic lines of force cut per second by the armature. This in turn depends upon the strength of the magnet and the speed with which the armature turns, and the number of coils of wire in it. But remember the armature cannot be turned without power. Hence the importance of dams to furnish the energy of falling water to turn the huge armatures in power stations. This doesn't necessarily mean that all generators are huge. Millions of small generators are used in automobiles, trucks, busses, airplanes, and trains to produce the electricity that aids in their operations. The generator is the device in the engine of your automobile which generates electricity to charge the battery.



291 *Using a split-ring commutator, this simple dynamo, or generator, delivers direct current. As the coil of wire, or armature, turns in the magnetic field, it cuts the lines of force in one direction. The current of electricity produced in the coil flows out through one half of the split-ring commutator. As it keeps turning, the coil of wire cuts lines of force in another direction, but the other half of the split-ring commutator sends the current produced in the same direction as the first flow. Because the current, or flow of electricity, is always in the same direction, it is called direct current, or D.C. Do you have direct current in your home?*

MAKING USE OF ELECTRICITY

In making any use of electricity brought to you by transmission lines, you will want to know how much you need of it, how long you will need it, and how well it will do the job you want done. You will want to know how to measure its flow, the force of pressure of its flow, and how much you use.

MEASURING ELECTRICITY

Electricity flowing through a wire may be compared with the flow of water through a hose. You know that there is a pressure behind the flow of water in the hose, because it leaves the nozzle with great force. You also know that there is a certain amount of water leaving the nozzle of the hose.

The pressure that results in a flow of electricity through a conductor (like the pressure forcing water through a hose) is measured in units called *volts.* The electricity coming into your house has a pressure of 110 volts. Meters

that accurately measure this electrical pressure are called *voltmeters.*

The amount of flow or current of electricity is measured in units called *amperes.* An ampere measures the flow of electricity or number of electrons that pass any given point in an electrical conductor in one second. Again we have delicate instruments to measure this flow. They are called *ammeters.*

In other words, while the volt is the unit for measuring the *pressure* of electrons, the ampere is the unit for measuring the *amount* of electrons passing through a conductor. As you may have guessed, "volts" and "amperes" are named after the scientists Volta and Ampère.

You can see marked on most electrical devices in your home the number of volts and amperes that they take. The number of volts and amperes shows you the pressure and flow of electricity needed to operate any electric device. And you can often see another marked unit called a *watt,* named after James Watt, who gave us the term "horsepower." One horsepower is equal to 746 watts. A watt is the unit that measures electricity in terms of power. Power, as you remember, means the rate of doing work. For example, about 600 watts of electric power are used in heating your flatiron. Sixty watts of electric power are used in lighting one of many electric light bulbs in your home, and 1,500 watts of electric power to heat a burner in your electric stove. How does this electric power get to your home to be used?

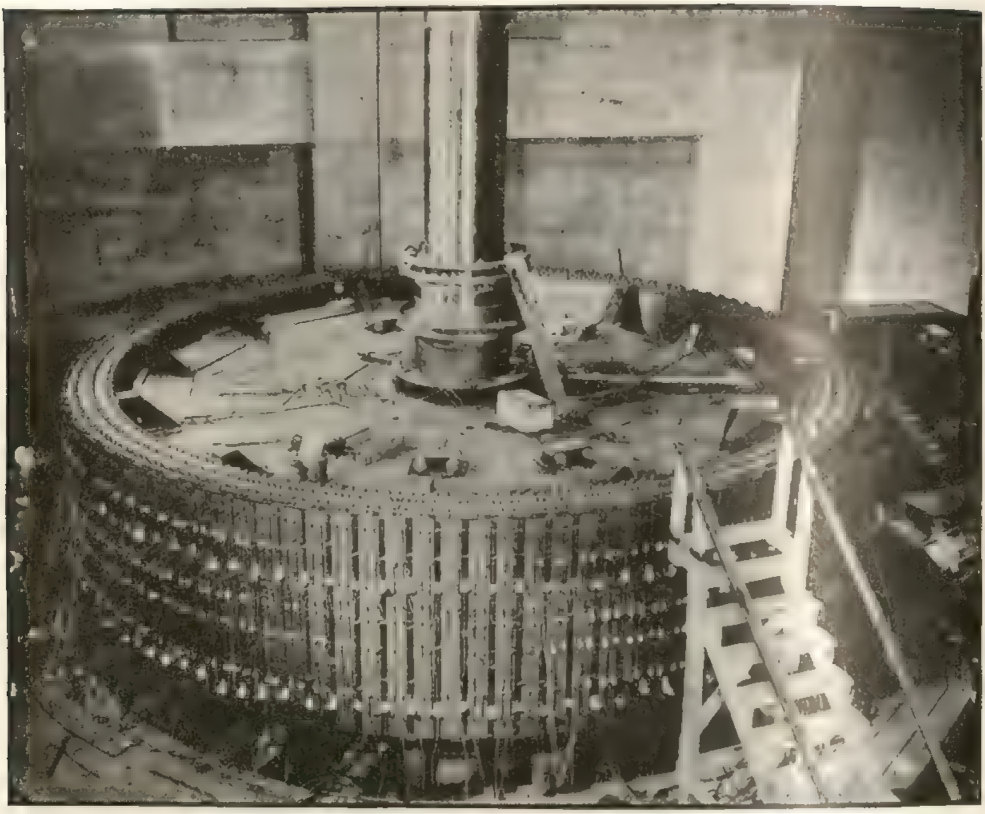
FROM POWER STATION TO YOU

Anyone who visits the power stations at Niagara Falls, the Grand Coulee, or any TVA (Tennessee Valley Authority) dam, will stand in awe as he hears the powerful hum of giant generators (Fig. 292). Electricity is being generated. Where does it go? That would seem easy to answer, wouldn't it? Let's just take some large copper wires, insulate them well with heavy rubber, and send the current into them. Then we put up poles and lead these wires over the country into homes. Unfortunately, the problem isn't as simple as that.

For instance, certain generators at Niagara Falls produce some 2,200 volts, while your home electrical appliances use 110 volts, a difference of 20 times in pressure. If 2,200 volts went into your house wires, it would create a real danger to life and property. Obviously the high voltage must be reduced to the useful 110 volts. Or, as scientists say, the high voltage is transformed to a low voltage by means of a device called a *transformer.*

TRANSFORMERS

Suppose we make a transformer. We may take a steel ring and wind two coils of wire around it. The first coil, connected to a source of alternating electric current, may have 40 turns of wire. In the second coil, entirely separated from the first, we have 20 turns. This second coil we have connected to a voltmeter. This instrument can tell us the voltage, or electric pressure. Now if we send 10 volts into the first coil (of 40 turns) and measure the voltage produced in the second coil by the voltmeter, we find the voltmeter reads not 10 volts, but 5. If we send 20 volts into the first coil, we find the voltage 10 volts in the second coil. Thus the voltage in the second coil is one-half the voltage sent into the first coil. Clearly, it is the difference in the number of turns of wire in the first and second coils which is responsible for this occurrence. The ratio of 40 turns of wire to 20 turns of wire is 2 to 1. The voltage is also reduced 2 to 1 (10 volts to 5). A



292 *An armature of one of the great generators for the Grand Coulee Dam, in process of construction. Each segment is connected to thousands of turns of wire. Speeding in a tremendous magnetic field, this armature will produce a huge electric current.* (*Newport News Shipbuilding and Drydock Co.*)

transformer operates in the simple way we have described.

There are step-down and step-up transformers. Step-down transformers reduce the voltage; step-up transformers increase it. The voltage can be stepped down by reducing the number of turns of wire in the second coil; it can be stepped up by increasing the number of turns of wire in the second coil.

A big generator at Niagara Falls produces 2,200 volts. This electric pressure (2,200 volts) must be increased to a greater voltage, or pressure, to send a current of electricity through many miles of transmission lines. So the pressure may be stepped up to 22,000 volts by a transformer and sent over transmission lines to Buffalo, let us say. To step up 2,200 volts to 22,000, you would use a transformer in which the number of turns in the second coil is 10 times as great as the number in the first coil (22,000 volts is $10 \times 2{,}200$). Suppose you wanted to step the voltage down from 22,000 to 2,200 volts. You would use a step-down transformer in which the first coil has 10 times as many turns as the second coil. Then to use the current at home you might use a second transformer to step the 2,200 volts down to 110 volts. How?

$$\frac{2{,}200 \text{ volts}}{110 \text{ volts}} = \frac{20}{1}$$

Thus you might use a transformer with 20 times as many turns in the first coil as in the second.

Next time you see the black boxes on the poles carrying the heavy transmission lines, you will recognize them as transformers. We now know that the voltage of the current which the transformer puts out depends upon the number of turns in the two coils. If the number of turns in the second coil is greater, the voltage of the current is increased; if it is less, the voltage is decreased.

HOW TO READ A METER

Like most sources of energy, electricity must be paid for. Electric power companies charge for the electricity they supply. They measure the power you use in *kilowatts*. A kilowatt is a thousand watts. Each consumer of electricity is charged for what he uses by the kilowatt hour (a thousand watts an hour). Have you ever looked at your electric light bill? If you haven't, do so now and find out how much electric energy in kilowatt hours your house or apartment used this past month. Compare it with the amount used at other times of the year.

Electric power companies install meters to measure how much electric energy a home uses. Do you know how to read your meter? Here is how it is done.

You will notice that your meter has four dials (Fig. 293). Each dial is numbered from 0 to 10; that is, up to ten kilowatt hours. From right to left this number of kilowatt hours (from the first dial) is multiplied by 10 for each dial; that is, the second dial from the right reads from 10 to 100; the third from the right, 100 to 1,000, and the fourth from the right, 1,000 to 10,000. In reading a meter, take the left-hand dial first and read the figure last passed by the pointer. Do the same for each successive dial from left to right. The result is the total number of kilowatt hours used by your home since the installation of the meter. Read your meter for two successive days. You will get an idea of how much electric energy you use each day.

SERIES AND PARALLEL CONNECTIONS

Have you used Christmas tree lights that were connected in *series* (Fig. 294 left)? In that case, you know that when one light goes out, all go out. That happens because the complete electric circuit is broken by the broken filament of one light. For this reason, series connections are never used in wiring houses. However, they are used in connecting

293 *A typical electric meter for homes. Suppose the pointer on the left-hand dial were between 1 and 2; the second between 4 and 5; the third between 2 and 3; and the fourth between 7 and 8. You would read 1,427 kilowatt hours. (Westinghouse)*

dry cells to increase the power of one by the number of cells so connected (Fig. 295). Thus in your flashlight each dry cell is connected in series with the next so as to increase the power of the light.

Parallel connections are used in wiring homes (Fig. 294 right). If one light goes out, the others are not affected because a complete circuit is not broken for the others. Each electric appliance is connected as if it had its own circuit. When the appliance is turned on, it makes a complete circuit by itself.

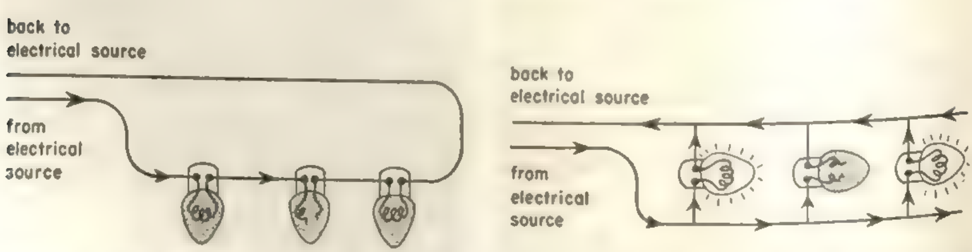
The use of parallel connections, however, allows more electric current to flow through house wiring as each succeeding light or electric appliance is turned on. Again you may compare this flow of current to a flow of water through pipes. The more pipes—or connections between the pipes—to carry the flow, the more flow is required to fill the pipes. The larger the diameter of each pipe, the easier it is for the flow of water to pass through.

So it is with electricity. Wires carrying a current of electricity through a house must be thick enough to carry the flow of electricity safely, even if all the lights and other electric appliances are turned on at the same time. The thinner the wire, the greater its *resistance* to the flow of electric current. This resistance produces heat.

HANDLING ELECTRICITY SAFELY

Many fires are caused by faulty wiring of houses, either by using unprotected wires or wires too thin to carry the flow of current. Wires carrying electric current must be carefully insulated; that is, they must be covered with a nonconductor of electricity like rubber. When the insulation is broken, the heated short-circuited wires may start a fire. Also when the insulation around a wire is frayed and the wire is exposed to the touch, there is great danger of injury. The electric current may go through the body instead of through the wire. Never touch a frayed wire unless the plug is first removed from the wall socket.

There are safety devices called *fuses* which break the electric circuit when the circuit is "overloaded." A circuit is overloaded when too much current enters it. Fuses are placed in metal boxes, and the incoming current passes through low-melting alloy wires in the fuses (Fig. 296). The heat (due to the overloading of electric current in the wires) melts the fuse-wire and the connection is broken. Overloading the circuit is caused by the use of too many electric appliances at one time. But the



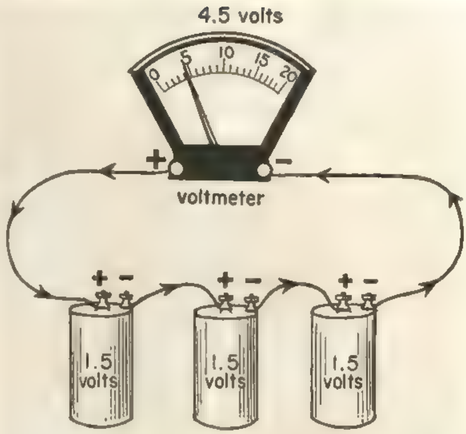
294 (Left) *If one light fails in a series circuit, all lights go out. Has this happened to your Christmas tree lights?* (Right) *If one light fails in parallel connection, other lights still glow. Have you had to replace an electric bulb recently? Were other lights still on in your home?*

most frequent cause of this alloy wire's melting, or (as you have probably called this melting) "the fuse blowing," is a "short circuit." In the ordinary circuit, electric current goes from its source to an electric appliance, say a toaster, and back to its source. A short circuit is caused when two bare wires carrying electricity to and from your toaster touch. Instantly a large electric current finds an easy passage back to its source. The heat produced in the wires is so great that the bare copper melts and sparks fly where the wires touch. However, the heat also melts the wire of the fuse, and until the correct fuse is replaced, you are without electricity in your house. It is important, therefore, that all cords to electric appliances be inspected regularly and replaced when necessary. In this way, short circuits may be eliminated.

It is even more important that neither you nor any one of your family make yourselves the short-circuiting agent. Many deaths are caused because safety rules are overlooked. It is well worth repeating them.

Rules for Dealing with Electricity

1. Never touch a bare wire carrying an electric current.
2. Do not put your finger into any electric socket.
3. Do not turn on an electric light or handle an electric appliance when your hands are wet. You may get a "short circuit" through your fingers or body.
4. Do not, while in the bathtub, turn on a switch or handle an electric appliance. This is extremely dangerous. The electron flow may go through your entire body.
5. Never leave a flatiron, toaster, electric heater, or any similar heating appliance "on" when you leave the house. These may cause a fire.

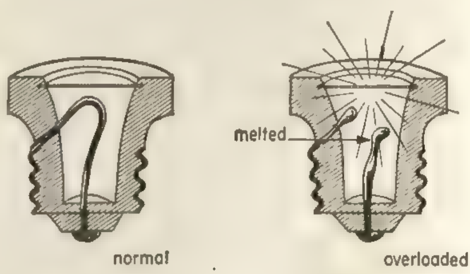


295 *When dry cells are connected in series, the total voltage is found by multiplying the voltage of one cell (1.5 volts) by the number of cells connected.*

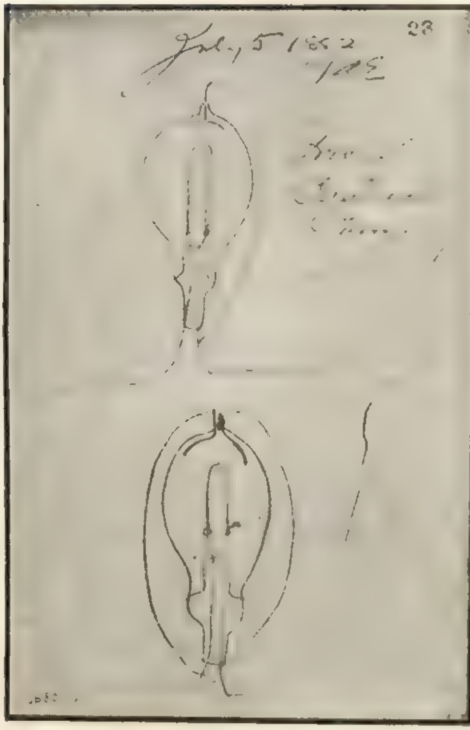
Don't forget these rules. Electricity is a very safe servant if you, too, play safe.

LIGHT FROM ELECTRICITY

Thomas Edison was the first scientist to succeed in getting useful and practical light from electricity. He had many problems to work out. First he needed a filament which would be fine enough so that it would resist the passage of electricity. This resistance must be so



296 *The fuse wire in a fuse melts with the heat of an overloaded electric circuit. Where are the fuses placed in your home wiring system?*



297 *Edison's diagram of one of his many attempts to produce a successful bulb. Note his initials. How do the electric bulbs in your home differ from the one in his diagram?* (*Thomas Alva Edison Foundation*)

great that the filament would heat up to a glow. The filament must be a substance that even at this heat would not melt. He finally found a carbonized thread to be the answer to his problem. He had to prevent the oxygen of the air from combining with the filament and causing it to burn. He solved this problem by sealing the filament in a globe of glass from which the air was removed by a vacuum pump.

He also had to find a method of connecting the ends of the filament to a base in the bulb so that when the base was put into a socket, a complete electric current was made. Edison also invented the base of the light bulbs you buy today.

How do today's light bulbs differ from those invented by Edison? Not too much (Fig. 297). In fact, except for the introduction of tungsten in place of carbon filaments, frosted globes to give a softer light, and a gas such as argon to give a longer life, they are the same. Modern manufacturing methods turn out millions of bulbs for every bulb that Edison made by hand (Fig. 298).

Most of the energy of the electric current flowing through an electric light bulb, unfortunately, is used in producing heat instead of light. For example, you cannot hold your hand on a 60-watt bulb that has been lighted even a short time. This inefficiency has led engineers to develop a *fluorescent* (flōō′ô rĕs′ĕnt) tube or lamp. The fluorescent tube gives off more light with less electric energy than the electric bulb. More of the electric energy in the fluorescent tube is used in giving light, not heat. One major disadvantage is that these tubes cannot be screwed into an ordinary electric socket, but require special installation.

USEFUL HEAT FROM ELECTRICITY

No doubt you have wondered why some metals conduct electricity easily, and others offer great resistance to it. The reason is not clearly understood, but it is thought to have something to do with the disturbance or transference of electrons in the metal. Some metals have their electrons transferred easily; others do not. Copper is an excellent conductor of electricity. In some way when a flow of electrons from any source enters a copper wire, its own electrons transmit the current from one end of the wire to the other end of the complete circuit. However, many other metals, like *nichrome* (an alloy of nickel and chromium) offer a great re-

sistance to electric current. This resistance produces immediate heat. Thus nichrome wires are used in electric toasters, flatirons, and stoves. They glow red-hot as an electric current is passed through them. In this and other ways, we get useful heat energy from electricity.

POWER FROM ELECTRICITY

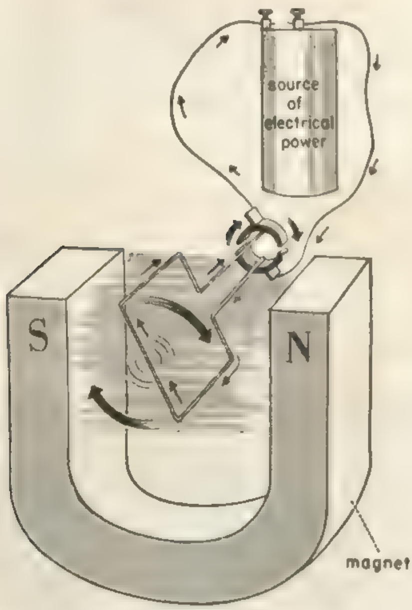
Look around your house. Are there any appliances that "run" by electricity? Have you an electric sewing machine, cake mixer, washing machine, vacuum cleaner, refrigerator, fan, radio, television set, deep freezer, or oil burner? Then you know how useful electric power can be in operating appliances that make your home a more comfortable and convenient place in which to live.

But electric power is not confined to the home. The motors that run our lathes and presses and the great machines of industry, those that turn the propellers of the largest ocean liners, and the wheels of monster locomotives are operated by electricity just like motors in your home.

Electric motors are generally built to operate by using either direct or alternating electric current, and they are labeled D.C. or A.C. respectively. However, many motors are universal motors; that is, they run equally well on A.C. or D.C. Electric motors are

298 *An incidental by-product of the age of electricity in which we live is the breath-taking skyline of New York City at night. (J. Walker Grimm)*

similar to electric generators in that they possess armatures, field magnets, and commutators (Fig. 299). The main difference between them is that in generators the armatures are turned by mechanical energy to produce electricity while in motors electricity is sent into the armature to produce mechanical energy. Thus if the armature of a D.C. motor is turned by mechanical energy, it can be used as a generator.



299 *Diagram of the operation of an electric motor. The coil of wire carrying an electric current throws out magnetic lines of force. Each side is a north or south pole, depending on the turn of the split-ring commutator, which alternates the current from the electric source. At the same time the field magnet attracts one side of the wire and then the other side, with its opposing north and south poles. An ordinary electric motor has thousands of turns of wire in the armature and a large magnetic field. With pulleys or gears attached to the shaft of the armature, electric motors run many of today's machines. Does your washing machine have an electric motor?*

Electric motors always operate because of electromagnetism. In the center of the motor there is an armature mounted on a shaft which is free to revolve. The armature contains coils of wire. The armature on its shaft is surrounded by other coils. An electric current is passed through the armature of the motor making electromagnets of the coils of wire in the armature. These coils, like all electromagnets, now have north and south poles. In many motors an electric current is also passed into the coils that surround the armature. This current produces a magnetic field with north and south poles. Each north pole in the armature is attracted to the south pole in the surrounding magnetic field. Each south pole in the armature is attracted to the north pole in the surrounding magnetic field. In responding to this attraction, the coils of the armature move. Since they are attached to a shaft, they move that shaft which turns over and over in its mounting in the motor.

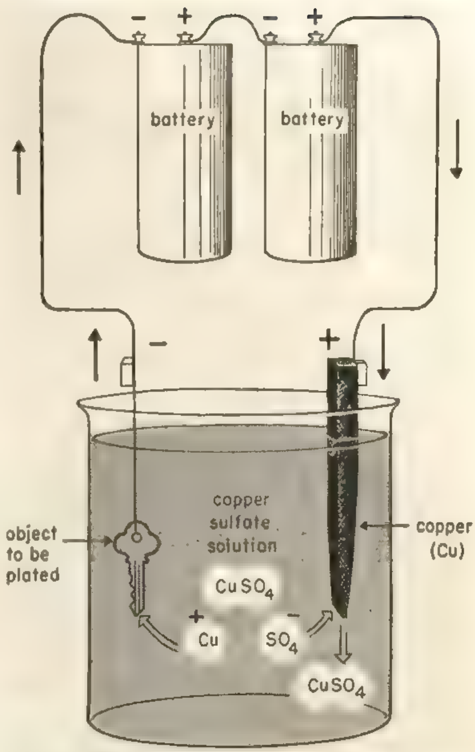
Many electric motors transmit power by a pulley attached to the shaft of the armature and connected by a belt to another pulley on the shaft of a machine. Electric motors vary in power from the smallest, about $\frac{1}{1000}$ horsepower, to giants the size of an ordinary room, which develop 40,000 horsepower. Electric motors are so efficient in operation (about 70 per cent) that where electricity is easily available they have replaced other methods of producing power.

ENDLESS USES OF ELECTRICITY

In this chapter there is not enough space to describe all the uses to which

electricity is put. But we can mention a few of the more common ones. Have you wondered how the bright chromium finish was put on automobile trim and bumper? Or how your silverware was plated with silver? Electroplating is done by passing an electric current through a solution of the metal which is to be put on as a finish. In the solution of the metal you need positive and negative poles. For instance, if you wanted to plate a metal article with copper, you might pass a current of electricity from two dry cells through a solution of a compound of copper, generally copper sulfate. The positive pole (Fig. 300) is made of copper. The electric current causes the copper which composes the positive pole to be transferred to the negative pole. This pole (attached to the negative or side pole of one of the cells) is the object you wish to plate (Fig. 300). Electrotyping—the making of the copper plate which printed the page you are now reading—is done in much the same way.

Treatment of the human body with electricity is known as electrotherapy. Ultraviolet and infrared lamps used in electrotherapy are operated by electricity. X-ray machines operated by electricity take pictures of the skeleton and internal organs of the body and are also used in the treatment of cancer and other diseases. Neon signs, television, radio, telephone, telegraph, movies—the useful or entertaining things that depend upon electricity seem endless. Electricity is indeed man's most useful servant.



300 *In plating objects with copper, silver, or gold, you must have a positive pole made of the metal. You must have a negative pole, the object to be plated. You must have a solution of a salt of the metal. Here it is $CuSO_4$, copper sulfate. As the current of electricity flows from the pure copper pole to the key, the copper sulfate solution delivers pure copper to plate the key. At the same time, part of the $CuSO_4$ solution unites with the positive copper pole to make more $CuSO_4$ solution. Thus the process of plating continues.*

GOING FURTHER

1 *Charging a balloon.* Blow up a balloon and hang it from a support. Rub the balloon vigorously with a piece of woolen cloth or fur. If your fountain pen is made of plastic or rubber, rub it briskly with the wool or fur. Bring the pen near the balloon. What happens? Take a glass rod (a glass towel rack or the insert to a Silex coffee maker will do) and rub that with a piece of silk. Bring the rod near the balloon. Is there attraction now? Remember

the rod is now charged with positive electricity and the fountain pen was charged with negative electricity. What charge is on the rubber balloon? How does this experiment help you to understand the simple electrical law concerning charges of electricity?

2 *Examining a dry cell.* Open a dry cell by breaking the composition top. Examine the contents. Find the following: the carbon pole, the mixture of manganese dioxide, ammonium chloride, carbon, the paper lining, and the zinc container. Are the insides really dry?

3 *Repeating Faraday's experiment.* Attach a coil of wire to a galvanometer. Thrust a bar magnet quickly through the coil. Does the needle of the galvanometer move? In what direction? Now pull the bar magnet quickly from the coil. In what direction does the needle move now? How does this experiment explain Faraday's discovery?

4 *Words are ideas.* Can you use these words in a sentence which will give their meaning? Use the glossary.

static electricity	parallel connection
voltaic cell	alternating current
lines of force	ammeter
storage battery	lightning
ampere	compass
series connection	magnetic field
electric motor	volt
voltmeter	kilowatt hour
dry cell	direct current
electric conductor	electric fuse
electric circuit	electric meter
watt	

5 *Put on your thinking cap.*

1. Two rubber balloons are blown up and hung from a support so that one inch of space separates them. Each one is rubbed with a piece of fur. Will the balloons now (a) come together, (b) swing farther apart, (c) remain as they are?

2. You move the floor lamp from one position in a room to another. As you push the plug into a socket, you notice that the cord appears frayed near the plug. When you move your lamp nearer your chair, suddenly all the lights in the room go out. Where would you look for the cause of the "short circuit"? What would you do to (a) make your floor lamp serviceable again, (b) make all the rest of the lights in the room light up?

3. Which would you think costs less to operate, a 60-watt lamp burning 12 hours or a 40-watt lamp burning 20 hours? (A kilowatt hour is 1,000 watts per hour.)

4. If you were wiring a house, would you use series or parallel connections? Why? What kind of wire would you use?

5. Wheat is ground into flour by delicate machinery which would be injured by the metal articles such as nails, screws, and bolts often found in carloads of wheat. Can you think of an easy method to extract these foreign articles from the wheat?

6 *Test yourself.* In your notebook, complete the following sentences with a correct word or phrase. Do not mark this book.

1. Electricity produced by friction is called . . . . . . electricity.

2. Like charges of electricity . . . . . . one another, while unlike charges . . . . . . one another.

3. Current electricity is a . . . . . . of electrons through an electric conductor.

4. When an electric current flows uninterruptedly from its source back to its source there is said to be a . . . . . . electric circuit.

5. Like magnetic poles . . . . . . one another; unlike poles . . . . . . one another.

6. The lines of force surrounding a magnet are called its magnetic . . . .

7. Electric current is generated when . . . . . . of force are cut by coils of wire.

8. The main parts of an electric generator are an . . . . . ., a field magnet, and rings connected to brushes.

9. The speed with which coils of wire in an armature turn through a constant magnetic field determines the strength of an . . . . . . current.

10. When a fuse "blows" in your home, it means that a . . . . occurred.

11. Parallel . . . . . . are used in wiring houses.

12. Series . . . . . . are used in batteries for your flashlight.

13. Electric motors as well as generators of electricity could not operate without ...... fields.

7 *Adding to your library.*

1. Are you interested in building your own laboratory and experimenting in the field of electronics? Here is the book for you: *Fun with Electrons* by Raymond F. Yates, Appleton-Century, 1947.

2. *Boys' Book of Science and Construction* by Alfred P. Morgan, Lothrop, Lee and Shepard, 1948. Chapter 8 covers the fundamentals of electronics plus a section on radio, telegraph, and television.

3. *Men and Volts* by John Winthrop Hammond, Lippincott, 1941. This history of the General Electric Company will show you how electricity has been developed to power our nation.

CHAPTER 24

MODERN PACK HORSES

Suppose you could travel around the world in seven hours—travel at the rate of almost 4,000 miles an hour. Actually, man-made rockets have achieved that speed and if maintained, it would send a rocket around the earth at the equator in seven hours. If such rockets could travel to the moon, they would make the trip—and back—in five days!

Rockets operate on the principle of the skyrockets you see shooting into the air in fireworks displays on the Fourth of July. Except, of course, that skyrockets are very much smaller and use gunpowder for fuel.

Like all engines, rockets depend upon fuel. The distance any rocket can travel depends upon the amount of fuel it can carry to thrust it forward. The fuel in a V–2 rocket is a mixture of liquid oxygen and alcohol which burns fiercely for only a little over a minute. Yet in this short time the rocket has traveled over 50 miles straight up and continues upward another 50 miles or so under its own momentum. Today, rockets with improved fuel and other devices have traveled nearly 300 miles above our earth.

Ever since man learned he could run faster than he could walk, he has been discovering new ways to travel faster. It is quite possible that some day man may travel clear out of the earth's envelope of air in rockets at fantastic speeds, if he can stand the initial thrust and if the rocket can carry enough fuel. In this chapter, however, we shall concern ourselves with travel

on land, on the sea, and in the air. You will learn that it is not just by accident that a train has certain kinds of rails, or that an airplane has wings. You will learn why a ship floats in water, and why a submarine can sink or float. You will learn how modern science is constantly devising better ways—more economical ways— to get you where you want to go speedily and safely.

ON LAND

The Duryea brothers in the United States certainly had a difficult problem to solve. They were building the first automobile.

THE FIRST AUTOMOBILE

From your study of the gasoline engine on page 392, you learned that its power turns a crankshaft, to which may be attached pulleys or gears that operate other machines. The Duryea brothers had the problem of connecting the crankshaft of their engine to the wheels of a wagon so that the engine might turn the wheels when the operator decided to move. So they invented the "clutch." By pushing a pedal, they were able to connect the power of the engine to the rear wheels or to disconnect it. The axle of the rear wheels was connected to the clutch by a chain, which ran over sprockets, as does the chain on a bicycle. When the clutch was engaged the engine caused the chain to move the rear axle and rear wheels. The first successful trial of the Duryea automobile took place in 1892. That year marks the beginning of the automobile age.

THE MODERN AUTOMOBILE

Modern automobiles bear slight resemblance to the first ones. The modern engine has four to eight cylinders and it is powerful and smooth-running. In the majority of cars, the engine is in front of the driver. It is not crosswise to the frame as in the first automobiles. The engine is connected to the rear wheels by means of gears, which are responsible for moving the wheels. These sets of gears, called the *transmission* and *differential*, not only turn the rear wheels but also can reverse the direction of the motion of the car.

In 1913, the first automobile with electric lights and a starter was produced. It was not until 1924 that automobiles were given four-wheel brakes. When the brakes are applied to the wheels, the car stops. Brakes and lights are the most important safety features of modern cars. To be able to come to a stop quickly and to see at night are so necessary for safe driving that many states have inspection dates for brakes and lights.

SAFETY ON THE HIGHWAYS

It is a long time from 1894, when there were only 30 automobiles in the United States, to today, when there are over 30,000,000 automobiles and over 7,000,000 trucks on the highways. The majority of drivers drive carefully. Most pedestrians also follow safety-first rules when walking or crossing busy streets. But still the toll of dead and injured from automobile accidents amounts to hundreds of thousands in the United States each year.

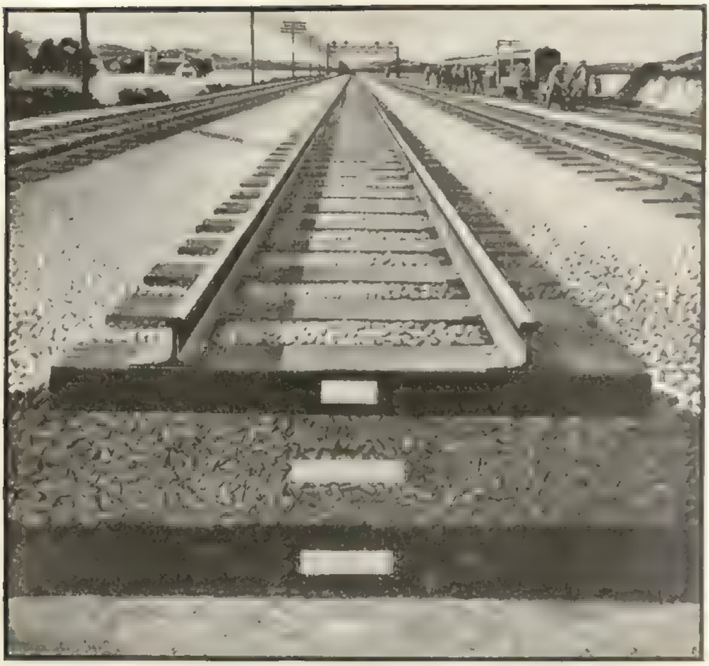
Most automobile accidents are caused by careless or reckless driving. Sometime you may drive an automobile. Let us hope you will drive it carefully. Remember that the average modern car weighs over 3,000 pounds, and it is probably capable of speeds over 80 miles an hour. Even at 35 miles an hour, it has a tremendous amount of

301 *This is what happens because of careless driving. The impact of a fast-moving car is tremendous. (Department of Public Safety, Commonwealth of Massachusetts)*

kinetic energy. At 35 miles per hour, a modern automobile has a striking force of over 156,000 foot-pounds. Such force is more than enough to break off a telephone pole or a small tree, or to kill a pedestrian (Fig. 301).

Moreover, if a car strikes an object like a tree or telephone post, the car stops immediately, but the passengers continue to move forward at 35 miles an hour. This is due to their inertia. Thus although the car has stopped suddenly, the passengers are still in motion. Do you wonder that persons are thrown through windshields and that the driver's body often crumples the steering wheel in accidents of this sort? And 35 miles an hour is a relatively low speed with the modern automobile. The greater the speed, the worse the effect when objects are struck. When carelessness, excess speed, and an unsafe highway are involved, the chances of an accident multiply. That is why deaths and injuries from automobile accidents exceed 100,000 a year.

Yet transportation by automobile and truck is an absolute necessity in modern American life. Indeed, large sections of this country lack any other means of travel. The automobile makes possible the building of homes far from bus and railway lines. Doctors can reach patients quickly; firemen can rush their apparatus to fires quickly; and the police can protect wide areas with only a few men. Food flows swiftly and smoothly by truck over America's three million miles of road. Everything that you use each day has been carried all or part of its way to you by truck. Unlike trains, trucks can vary their schedule and their routes between shipping and delivery points. Without



302
The modern T-rail. Why does it have this shape? (Al Paul Lefton Co.)

trucks America's economy would be in peril.

THE STEEL RAIL—A TRIUMPH OF ENGINEERING

While our way of living makes us depend heavily on trucks, we depend even more on trains. Most of our big industries would shut down in a short time if railroads stopped carrying heavy freight.

The next time you go to a railroad station, look closely at the rails. In cross section a steel rail is T-shaped with a broad base and narrow top (Fig. 302). This T-shaped rail represents a hundred years of study and experiment. The first rails for trains were made of wood with iron bands fastened to the top. From these first rails to those used today, there have been seventeen different changes in design. The top of the modern rail is constructed to fit and hold the flanges or overhanging sides of the car wheels. The stem of the T is designed to be strong enough to distribute hundreds of tons of weight over the area of the broad base. At present no other design is so satisfactory. It is a very simple design, yet a great deal of research was required to produce it.

In 1832, there were only 40 miles of railroad in the United States; in 1861, 30,000 miles; in 1880, 94,000 miles, and today 400,000 miles of steel T-track carry each year a billion passengers and two and a half billion tons of freight.

THE MODERN RAILROAD TRAIN

Modern railroad engines show a spectacular contrast with Stevenson's first engine, or with the engines that drew trains in 1861, in 1880, or in 1905. The fastest recorded run by a locomotive was made in 1905 at 127 miles an hour at Elida, Ohio. This run, however, was a test speed run over a three-mile stretch of straight track. But modern locomotives do not make such test runs. With safety considered, the

fastest modern locomotives average, with stops, little more than 60 miles an hour over long distances. Many of these locomotives draw streamline trains with cars coupled together so as to make the entire train seem one unit. Some cars have glassed-in observation seats in their roofs. Many have the comforts of the best hotels (Fig. 303).

Railroads have searched ceaselessly for economy of operation. On short runs, gasoline- and kerosene-operated engines have been used. Electric engines without fumes or smoke draw trains through large cities. The introduction of the Diesel engine, with its streamline train, has also helped lower operating costs. Diesel engines power generators which in turn send a current of electricity to motors. These motors, geared to the wheels, roll the engines swiftly along. Recently a coal-burning steam turbine locomotive was developed that generates electric current for motors on the driving wheels. It compares well with the Diesel in economy of operation.

Yet steam may not go out of use. All over the United States there are steam locomotives that will pull freight and passenger trains and switch cars in freight yards for years to come.

ON THE SEA

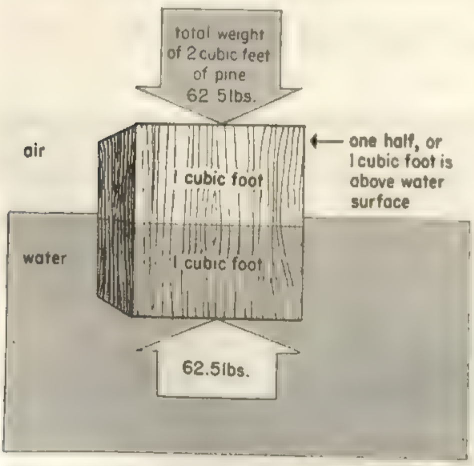
Only 150 years ago, the first steamboat, with sparks and smoke belching from its stack, chugged along against wind and tide. That was a great day. For many hundreds of years men had depended on wind and tide to take them out of harbors and over the sea. No longer would men have to wait for a favorable wind or tide. Now great steel vessels weighing thousands of tons go at will to all the harbors of the world. Although some of these vessels are powered by Diesel engines, most are equipped with high-speed turbines. These turbines are often connected by gears directly to the propeller shafts. On extremely large vessels the turbines operate generators which operate

303 *A Diesel-powered train with observation compartments on roofs of cars.* (*General Motors*)

motors that turn the propeller shafts. In the largest ocean liners each of the propellers is operated by a 40,000-horsepower electric motor.

HOW DOES WATER SUPPORT SHIPS?

Over 2,200 years ago Archimedes (är′kĭ mē′dēz) discovered that objects seemed to weigh less in water than in air. Archimedes also found that any object placed in water displaced some of the water. You can make the same finding if you drop a stone into a tumbler brimful of water. Some of the water overflows. But Archimedes went further. He weighed the water that overflowed. He found that the weight of the overflow water just equaled the weight that the object lost when placed in water. After many experiments, he developed a statement concerning his work, known today as Archimedes' principle. It is this: Any object placed in a liquid is buoyed upward by a force equal to the weight of the liquid displaced by the object.



304 *The 2-cubic-foot pine block is buoyed up in water by a force of 62.5 pounds. Why does half of it extend above the surface?*

An object will float on water if it displaces an amount of water equal to its own weight. A tiny, heavy object does not displace much water. Since it is heavier than the water it displaces, it sinks rapidly.

Suppose you had a block of dry pine wood two cubic feet in volume which weighed 62.5 pounds. If you put this block of pine into water, it would sink only halfway under and then float. The one cubic foot of wood below the water surface has displaced one cubic foot of water. One cubic foot of water weighs 62.5 pounds. The wood is thus buoyed upward by a force equaling its own weight (Fig. 304). But the volume of the pine block is two cubic feet. So one half of it, or one cubic foot, will stick up above the surface of the water. This is so because the entire block (two cubic feet) is only half as heavy as the weight of two cubic feet of water. From this, it is easy to explain why an empty rowboat floats higher in the water than does one filled with people.

WHY DOES A STEEL SHIP FLOAT?

You now see that an object floats when its weight is less than the weight of an equal volume of water. An object sinks when its weight is greater than the weight of an equal volume of water. Any object that sinks displaces a volume of water equal to its own volume. If one cubic foot of steel weighing 500 pounds is placed in water, it will displace a cubic foot of water weighing 62.5 pounds. Since its weight is eight times heavier than the cubic foot of water, the block of steel sinks rapidly.

But steel can be made to float. How? If you were able to cut the cubic foot of steel into thin sheets, you might fasten the sheets together to make a box about five feet long, five feet wide, and four feet high. Your box contains 5 × 5

$\times 4$ feet or 100 cubic feet. Will it sink? Remember the 100 cubic feet of the steel box still weigh 500 pounds. On the other hand, 100 cubic feet of displaced water weigh 100×62.5 or 6,250 pounds, more than 12 times the weight of the steel box. So the steel box, weighing 500 pounds, is more than 12 times as light as 100 cubic feet of water weighing 6,250 pounds. Thus the steel box floats well out of water.

So it is that large steel ships can carry heavy cargoes. To guard against overloading ships for dangerous ocean conditions, lines or figures are marked on the hull. These show port authorities how far a ship and its cargo sink into the water.

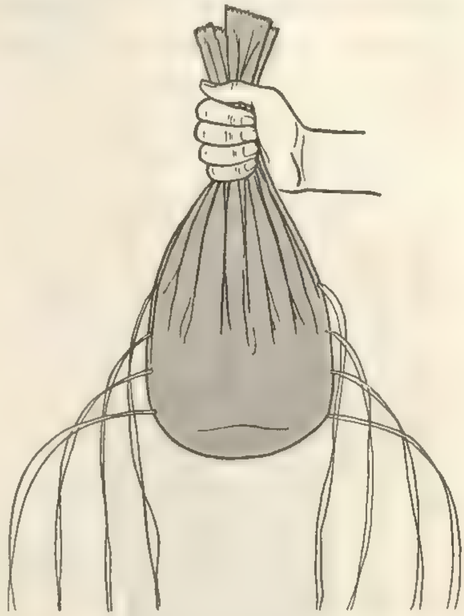
WATER EXERTS PRESSURE

You have learned that air presses on you from all directions at sea level with a pressure of 14.7 pounds per square inch. Two simple experiments will show you that water also has pressure and that this pressure is distributed in all directions. First, pour about two quarts of water into a heavy paper bag. Lift the bag carefully and punch four holes with a needle around the bag, about one inch from the bottom. Punch three more rows of holes, each hole one inch above the other around the bag. Note the force of the stream of water issuing from each hole (Fig. 305). From which holes does the water spurt farthest?

Next make a mark with a red wax crayon on the inside of a 10-quart pail, four inches from the bottom. Fill the pail with water. Stretch a thin piece of rubber over the end of a short thistle tube and fasten it with a rubber band (Fig. 306). Fill the bend of a U-tube with water and attach one end to the stem of the thistle tube with a piece of rubber tubing. Attach the U-tube to a ring stand with the face of a ruler immediately behind the open end of the U-tube. Insert the thistle tube into the pail until the rubber-covered end is opposite the red mark. Note what happens to the water in the U-tube. Since it rises as the thistle tube is pushed into the water in the pail, it will indicate there is pressure on the rubber covering the mouth of the thistle tube. Take a ruler reading of the upper level of the water in the U-tube. Turn the mouth of the thistle tube sidewise and then upward, keeping level with the red line. You will see that there is no change in the reading of the water level in the U-tube. Lift the thistle tube slowly out of the water. As the thistle tube rises, the water pressure goes down.

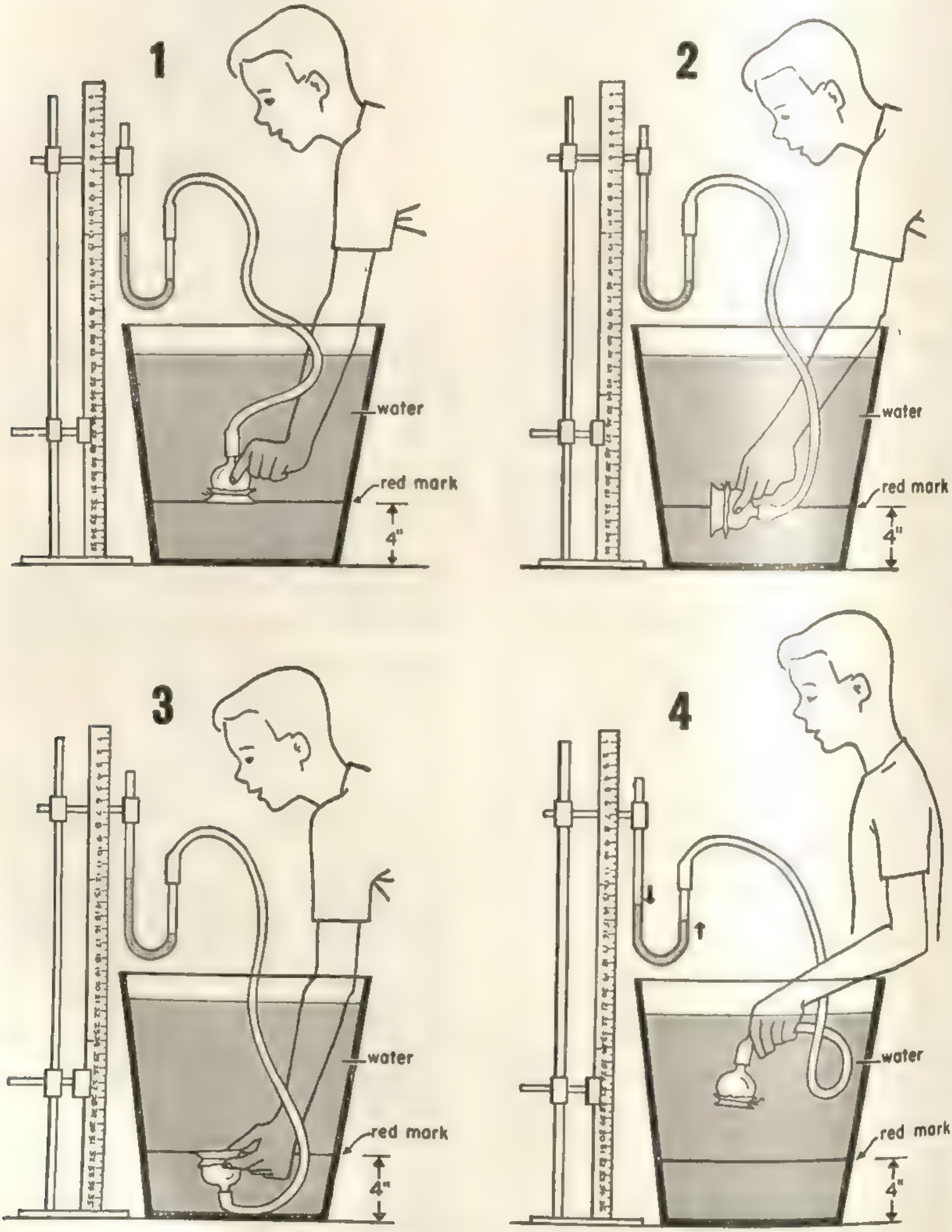
From this experiment you can conclude, as shown by the change of water level in the U-tube, that at one depth water exerts equal pressure in all directions. Does this pressure increase with depth?

305 *Why do streams of water spurt farther from holes near the bottom of the bag?*



DEEP WATER AND DIVING

Actually for about every 34 feet you go below the surface of water, the pressure at the surface (14.7 pounds per square inch) is increased by the same amount. Even if you dive only a short distance below the surface, you can feel this increased water pressure on your eardrums. Native pearl divers of the South Seas have been known to



306 *Water pressure, like air pressure, is exerted in all directions, as in 1, 2, and 3. If this pressure changes, as shown in 4, how does it affect the level of the liquid in the* U*-tube?*

dive to depths of over 100 feet. However, they often become deaf, crippled, or paralyzed after a few seasons of such work.

Clad in modern diving suits and breathing a mixture of helium and oxygen, United States Navy divers have gone down to depths of over 400 feet in practice dives. To withstand the pressure of water, most divers' suits are inflated by air at a pressure equaling the water pressure. Thus if a diver descends to a depth of about 130 feet, he may be breathing air at over five times ordinary atmospheric pressure. Under this great pressure nitrogen is forced into his blood. If the diver stays down too long and then is drawn to the surface too rapidly, this dissolved nitrogen literally "fizzes" out of his blood as the pressure decreases. It is somewhat like the action of carbon dioxide gas that fizzes out of a bottle of ginger ale when pressure is released as the top is removed. Nitrogen bubbles collecting in joints cause the diver terrific agony and result in a disease called the "bends," convulsive contortions that may result in paralysis or death. You may remember that to avoid this, divers are brought to the surface gradually or else they are placed in decompression chambers where the pressure is released slowly, allowing the dissolved nitrogen to work out of the diver's body at a safe rate.

The pressure of deep water has created problems for engineers who build huge dams (Fig. 308). They must calculate carefully the thickness of the base and the strength of the structure needed to withstand the pressure of the water held back. For example, Hoover Dam across the Colorado River is 726 feet high. Yet it is almost as thick at its base as it is high, and it gradually tapers toward the top as the need for thickness lessens with decreasing water pressure.

SUBMARINE TRAVEL BELOW THE OCEAN SURFACE

The credit for the construction of the first practical submarine goes to Simon Lake and John Holland, both American inventors. In 1875 John Holland built an underwater boat 60 feet long that could rise or sink by taking in and blowing out water. Simon Lake, interested in recovering sunken ships, further developed the basic principles of modern submarines (Fig. 307).

On both sides of a modern submarine there are many airtight compartments called ballast tanks. In these tanks are huge Kingston valves that work from a control inside the submarine. A Kingston valve is like a swinging door that may be opened or shut to let water in or out of the tanks. In addition, there are vent valves like small swinging doors at the top of these tanks. They let air out of the tanks. When the Kingston valves are open, no water can enter the tanks while the submarine is moving forward, unless the vent valves are open at the top to let air out. In other words, to let water into the tubes through the Kingston valves, the vent valves must be opened to let air out of the tanks.

To run partially submerged, ready for a "crash dive," the Kingston valves and the vent valves are opened. Air rushes out of the vent valves as enough water rushes into the tanks to bring the submarine level with the ocean surface. The vent valves are then closed and no water can enter the tanks unless air is let out of the vents. In submarine language the ship is then "running on the vents." In an emergency, the vent valves are opened, and the tanks are open to the sea.

Then water rushes into the tanks, and the submarine disappears as its weight increases.

If the submarine had no forward motion and no way of getting the water out of its ballast tanks, it would sink to the bottom of the ocean. But it has electric motors to run the propellers underneath the surface, and compressed-air tanks to blow out the water in the ballast tanks. When the commander wishes the submarine to rise, compressed air blows the water out of the tanks. The vessel is now lighter than an equal volume of water and it rises to the surface. Modern submarines have tubes, somewhat like periscope tubes, to take in air when submerged. You will read more and more of the so-called snorkel submarines which have these tubes. With these tubes they can remain submerged indefinitely and at the same time run on either Diesel or electric power.

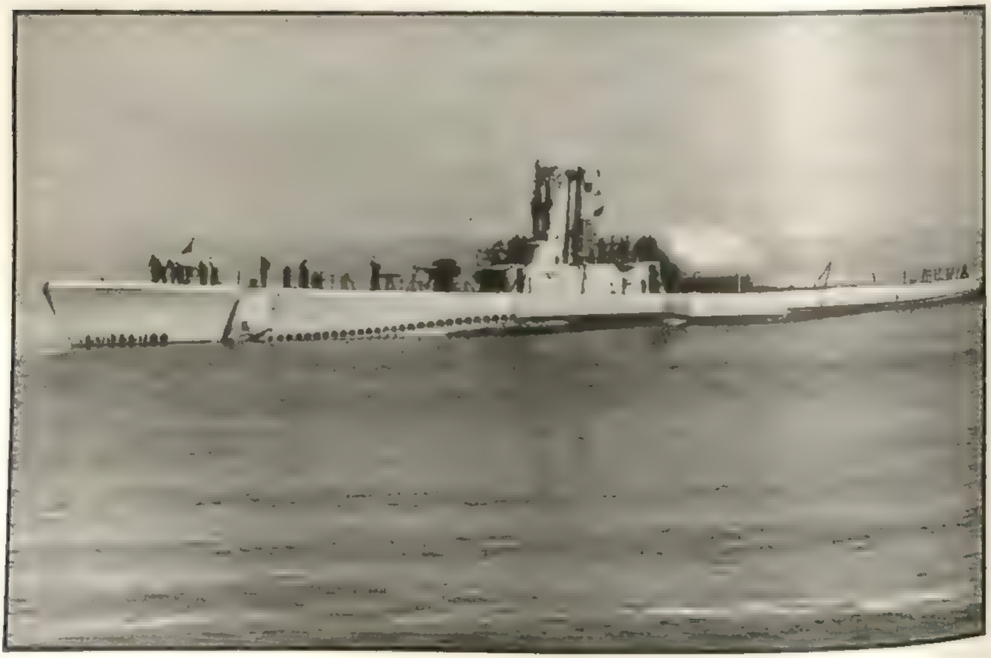
IN THE AIR

Just as oceans surround the continents so air surrounds the earth. The air contains living creatures just as oceans do. Oceans seem never at rest; neither is the air. No one has ever been to the bottom of the deepest ocean, which is over six miles down, and no one has ever been to the upper limits of the air. Scientists have been able to measure the deepest parts of all oceans, but there is no authority to tell us definitely how far the ocean of air extends above the earth. The best observations to date seem to indicate that there is some air at least 600 miles above your head.

THE AIR IS PARTLY EXPLORED

The deepest anyone has gone below the surface of an ocean is 4,500 feet (over four-fifths of a mile). This descent occurred in 1949 off the coast of Cali-

307 *The* U.S.S. Perch, *one of the latest fleet-type, troop-carrying submarines. Note the watertight storage compartment for amphibious landing equipment.* (U.S. Navy)



308 *One of the great dams of the world—the Hoover Dam, on the Colorado River between Arizona and Nevada. (Union Pacific Railroad)*

fornia when Dr. Otis Barton descended in his benthoscope. Dr. Barton described creatures living at a depth of nearly a mile under a pressure of tons of water on every square inch of their bodies.

The highest an airplane has ever flown is about 10 miles. The highest any man has gone is nearly 14 miles. Captains Stevens and Anderson rose to that height in 1935 in the National Geographic Society's balloon, "Explorer II." Samples of the rarefied air they took at that height contained living mold spores. How far down does life exist in the ocean? No one knows exactly. How far up does life exist in the air? No one knows exactly.

We know that air is not uniform everywhere above the earth. As one goes higher, the air becomes thinner. Up to about six miles or to the limit of the troposphere, the air grows from 15 to 25 degrees cooler each mile above the earth. Mountain climbers have never been able to reach the top of Mount Everest, the highest mountain in the world, because of both the cold and the difficulty of breathing.

In the troposphere exist all the air movements, storms, ordinary clouds, rain, and snow that we feel or see on the surface of the earth. At the top of the troposphere the temperature readings are 70 to 80 degrees below zero. Above the troposphere the stratosphere extends to an unknown height. Here the temperature stops falling and the air moves very little. It is here in the air ocean, above the storms and where air resistance is weak, that rapid travel of the huge transport planes of the future will take place. Of course, these airplanes will have to be "pressurized"; that is, in this area where air pressure is extremely low, the pilots and passengers will have to be furnished air at ordinary atmospheric pressure to breathe.

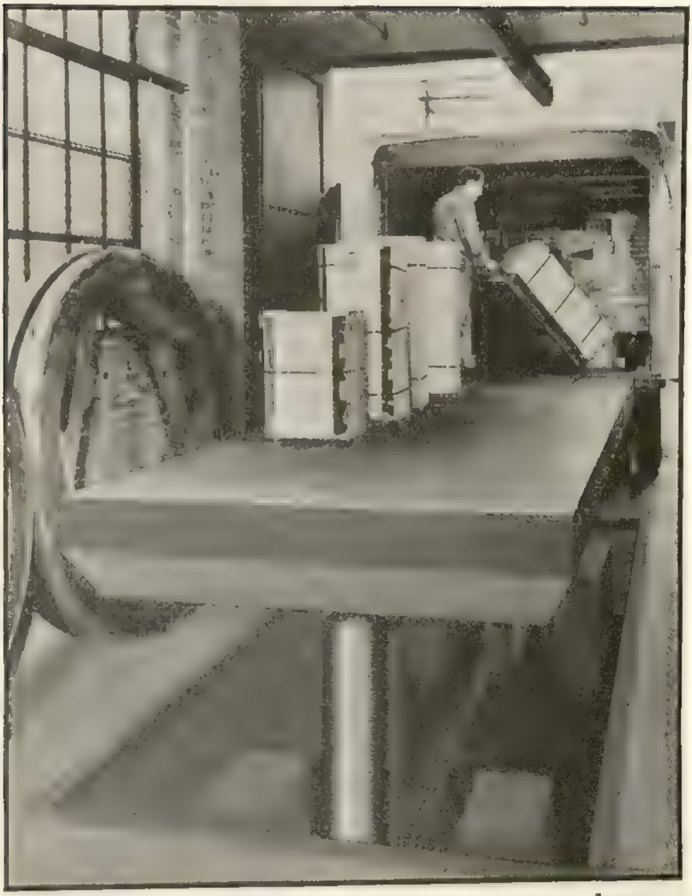
COMPRESSING AIR

If you fill a milk bottle full of water and attempt to push a tight-fitting cork stopper into the bottle, you find it difficult unless some of the water spills out. Water cannot be easily compressed. In fact, any pressure exerted on one square inch of surface of a liquid extends that same pressure all through the liquid in a vessel. The same pressure is multiplied by the number of square inches of surface with which the liquid is in contact. Suppose you strike the cork stopper of the filled milk bottle with a force of two pounds per square inch. Since the force would be transmitted equally to every square inch of surface of the inside of the milk bottle, its 200 square inches of surface would have to withstand a pressure of 200×2 or 400 pounds. This, of course, would break the bottle. Because liquids multiply force in this way, we have such machines as hydraulic jacks and lifts, where a small force on a small area of water or oil is multiplied thousands of times to do useful work (Fig. 309).

On the other hand, air can be compressed to such an extent that when released the force of its expansion can fill tires, operate air hammers, rock drills, and brakes on trains, busses, and trucks. To compress air, a piston forces it through a cylinder into an airtight tank. In such compressors, air pressure may be built up to hundreds of pounds per square inch.

WHAT DOES AIR WEIGH?

By using delicate scales, scientists have carefully measured the weight of air at sea level. They first weigh a strong container, then by using a vacuum pump they extract as much air as



309
A hydraulic lift raises heavy merchandise for storage or transportation. (Rotary Lift Co.)

possible from the container. When the container is weighed again, it is found to have lost a certain amount of weight. This loss of weight represents the weight of air the container held before the air was pumped out. By this method it has been found that one cubic foot of air at sea level weighs about 1¼ ounces. If your schoolroom is 30 feet long by 20 feet wide by 10 feet high, it contains 6,000 cubic feet of air. This air weighs 6,000 × 1¼ or 7,500 ounces. Since there are 16 ounces to the pound, 7,500 ounces equals about 468 pounds. Would you have believed before you read this book that most strong men in the world could not pick up and carry a weight equal to the weight of air in your schoolroom?

Because air exerts 14.7 pounds pressure on every square inch of surface at sea level, all the air surrounding the earth has a tremendous weight. Like water, air exerts this pressure in all directions.

As you go up in air, the pressure decreases because there is less air above you. This decrease is more or less at a gradual rate until at 14 miles the air pressure is only about ½ pound for each square inch.

THE AIRPLANE

Probably you are acquainted with many kinds of military and transport planes. However, there are four types of airplanes with different shapes or placement of parts: the monoplane,

the biplane, the flying wing, and the helicopter (Fig. 311). The monoplane has one wing; the biplane has two wings, one above the other. The flying wing consists of one huge wing containing most of the operating parts of the airplane. The helicopter has no wings as such, but rotating blades that take the place of wings.

Most airplanes have these parts in common (Fig. 310):

Ailerons (ā′lẽr ŏnz) are flaps set in the rear edges of airplane wings. When one is raised, the one on the opposite side is lowered. The pressure of air against the raised and lowered ailerons causes one wing to rise and the other to lower when in flight. This makes it possible for a pilot to "bank" or make a sharp turn with his plane. Sometimes both ailerons are lowered as in landings.

The body of an airplane is called the *fuselage* (fū′zĕ lĭj). In the front of the fuselage are located the pilots' seats, controls, and instruments.

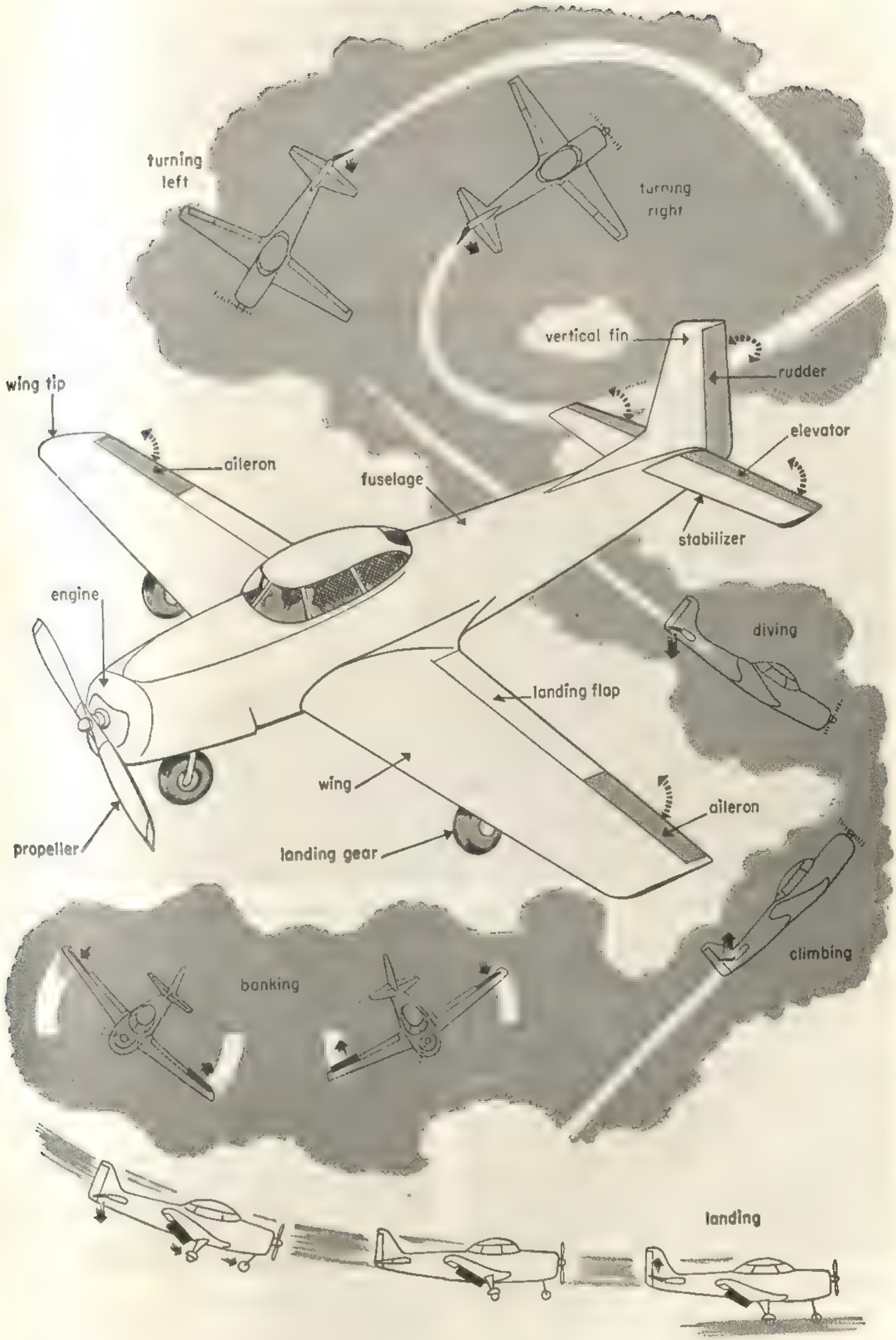
Most airplanes have *engines* and *propellers* mounted in the wings or in front of the fuselage. Air-cooled engines are generally circular in shape with metal fins on the cylinders to provide more surface for cooling. Liquid-cooled engines generally have cylinders in a straight line and allow for better streamlining. The engine provides power to turn the propeller. The propeller is attached to a shaft in front of the engine. The propeller may be multiple-bladed, and can be adjusted so that more or less air can be attacked by the blades.

Jet engines do not depend on propellers. Since they depend upon the thrust of hot gases from compressed burning fuel they have the advantage of greater power with less weight than either the heavy air-cooled or liquid-cooled types of gasoline engines. Jet engines are used mainly on military aircraft.

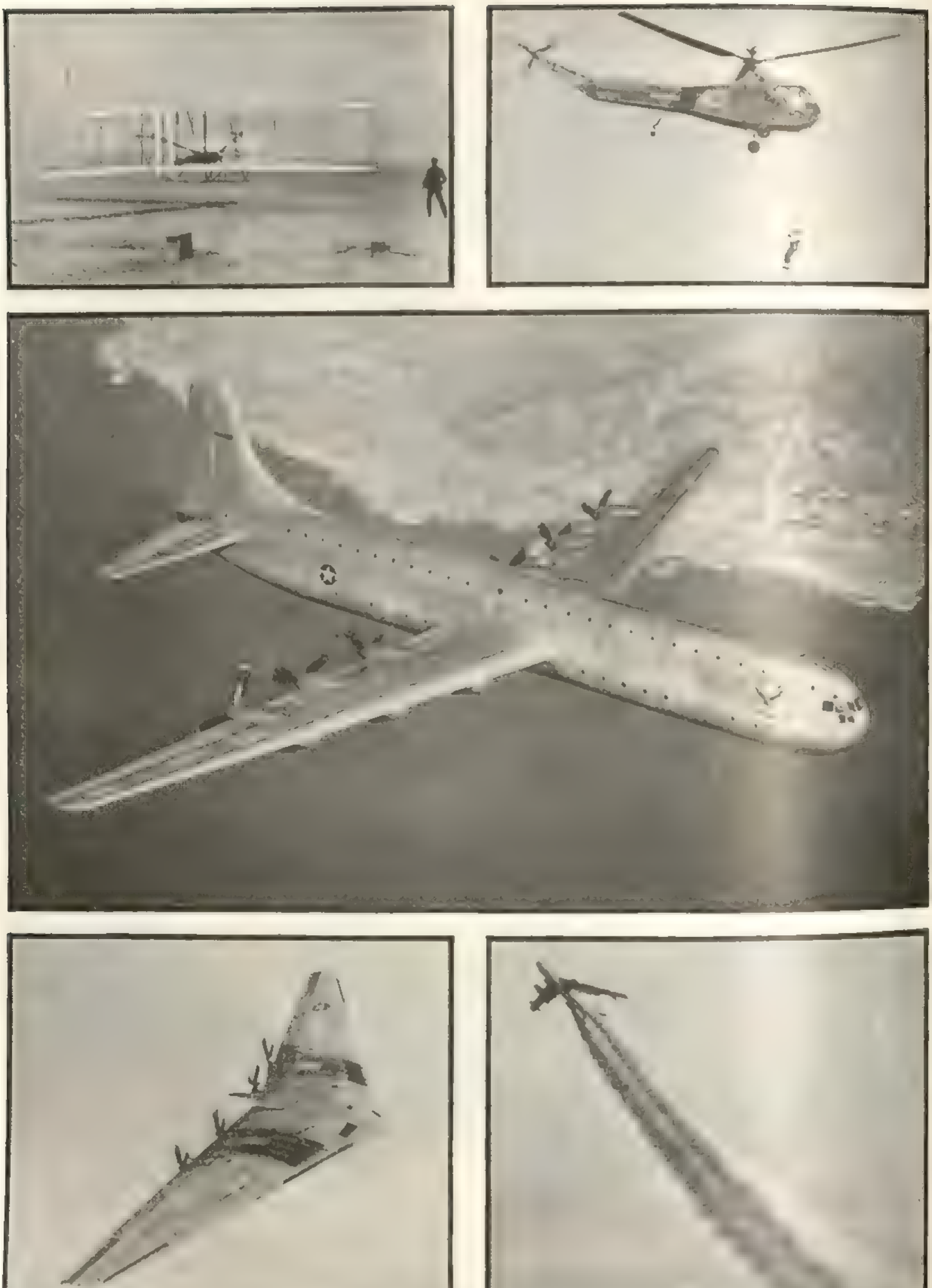
On the rear of the fuselage, or tail of the airplane, are mounted the surfaces that control the sidewise and up and down movements of the plane. A *vertical* fin rises from the upper part of the tail. The rear of this fin is movable from one side to the other. This movable part near the fin is called the *rudder*. In small planes, its motion is usually controlled by rudder bars or pedals operated by the pilot's feet. The purpose of the vertical fin is to keep the airplane headed straight in the direction it is flying. The purpose of the rudder is to make the airplane turn right or left from this course.

The *stabilizer* extends from either side of the bases of the vertical fin and at right angles to it. This stabilizer acts in a way similar to the vertical fin. Its purpose is to help keep the plane directly on its course. The *elevators* at the rear of the stabilizer are movable. The elevators can be moved upward or downward when the pilot pulls back or pushes forward a *control column* or "stick" near his seat. When the stick is forward, the elevators swing downward and the nose of the airplane dips downward. When the stick is pulled back, the elevators swing upward and the nose of the plane rises. In this way, an airplane may be made to dive or climb.

Most airplanes must have *wheels* to roll along the ground in order to get speed enough to rise into the air. Wheels are also necessary to land safely. Except for these purposes, wheels are not required. Thus they are often drawn up into the fuselage when the plane is in the air in order to cut down air resistance. Usually the under section or landing gear of a plane contains some type of shock absorber to cushion the



310 *The airplane and its most important parts. How are they used in climbing, turning, diving, and landing?*



311 (Upper left) *First successful flight by Orville and Wilbur Wright at Kitty Hawk, N.C. on December 17, 1903.* (*U.S. Army*) (Upper right) *A helicopter used for rescue work.* (*U.S. Coast Guard*) (Center) *Six-engined transport, largest of the U.S. Air Force.* (*Consolidated Vultee*) (Lower left) *Northrup Flying Wing.* (*Library of Congress*) (Lower right) *Jet-assisted take-off for a bomber.* (*Boeing*)

jolt when the wheels of the plane touch the earth in landing. On flying boats, pontoons absorb the jolt of landing in water.

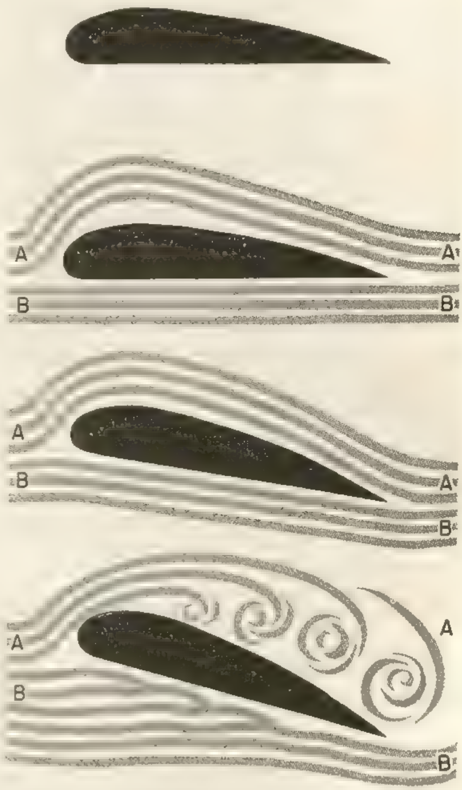
HOW DOES AN AIRPLANE FLY?

If you were asked to name the most important of all the important parts of an airplane, would you name the wings? You would be perfectly right. The next time you see an airplane, look closely at its wings from the front and side. You will note they are shaped as in the cross section (Fig. 312). This cross section is called an *airfoil.* If the curve of the airfoil varies so much as a quarter of an inch, the flight of the plane is affected. The right kind of curve is so important that scientists devote years to studying and designing the curves for various types of planes. To help them in this study of airplane wings, wind tunnels are used. Some wind tunnels are so powerful and large that winds of over 400 miles an hour are produced to test the wing design of full-sized experimental planes.

The purpose of an airplane's wing is to attack the air in such a way as to cause the plane to be lifted. Air meeting the curve of the upper portion of the wings is swept upward and over the curved surface (Fig. 312). The air currents, represented by AA and BB, take the same time to pass over and under the airfoil, but the currents AA travel the longer distance and therefore go faster in the same time than the currents BB. Thus the air over the wing travels faster than the air under the wing.

Over 200 years ago, a Swiss physicist named Bernoulli discovered that in a flowing fluid pressure decreases as the speed of the flowing fluid increases. It is much the same with air. Air flowing faster over the top of an airplane's curved wing produces less pressure than that flowing below on the flat surface. There is a higher pressure produced below the wing than above. The higher pressure underneath the wing forces the wing upward. This is known as *lift.* The lift must be greater than the weight of the plane or the plane cannot fly.

The pilot can increase the lift of his plane by pulling backward on his "stick." With the nose of the plane



312 *From top to bottom:* (1) *The airplane wing.* (2) *Air flowing fast over the top surface A creates an area of low pressure; greater pressure of air B, under wing, gives the airplane lift.* (3) *With the nose of the plane pointed upward, greater lift is achieved.* (4) *Too much angle of wing produces turbulence of air over it, and lift decreases.*

pointing upward, air flows even faster over the top of the wing, producing a lower pressure on top, and thus a greater lift. Therefore, there is a rapid climb.

The angle of the wing shown in Fig. 310 is called the *angle of attack*. The angle cannot be increased beyond a certain point because the air flowing over the rear sections of the wing "burbles" or becomes turbulent. When this happens, the airplane's speed slows down and the lift decreases sharply. Of course, in order to have any lift at all, the plane must have forward motion. This is provided by the propeller which bores into the air like a screw forced into wood or like a boat's propeller blade into water. This motion is called a *thrust*. The thrust also causes the air to flow over the wings. The *drag* of the airplane which resists the thrust is the resistance of the air to the movement of the body of the plane. Streamlining of planes has greatly reduced drag. But to fly safely an airplane's thrust must be greater than its drag.

JET PROPULSION

Sir Isaac Newton, one of our great scientists who worked in the seventeenth century, made a study of motion. After many experiments and observations, Sir Isaac published his findings, called "The Laws of Motion." His third law, that which helps explain a basic principle in the operation of jet-propelled planes, is this: "For every action there is an equal and opposite reaction."

Even the ancient Greeks had an idea of this. For example, they knew that steam pushed out from a container of boiling water with great force (Hero's engine, p. 385). Had they had the advantages of later science, they might have built a steam carriage like one of Sir Isaac Newton's designs. This consisted of a large container of boiling water just behind the driver's seat. A valve let the steam out of a jet, facing the rear. The push of the steam backward, Sir Isaac figured, would make the carriage go forward. But the carriage was impracticable. No driver wanted a seat near a boiler—especially one that might blow up at any moment!

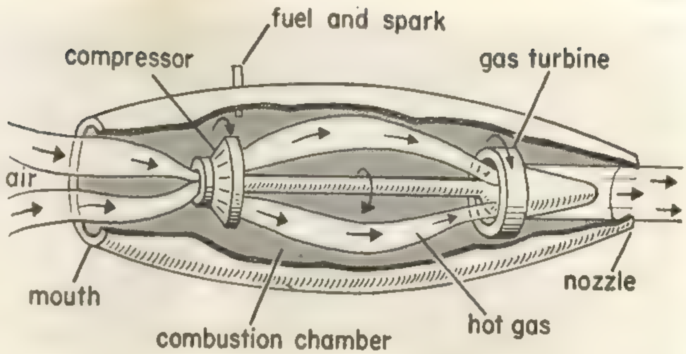
THE PRINCIPLE OF JET PROPULSION

Anyone who can blow up a small rubber balloon can learn something about Newton's third law of motion. He also may learn something about jet propulsion. Blowing the balloon full of air and suddenly letting it go, he sees the balloon darting this way and that —finally coming to rest only when the swish (or force) of the confined air ceases to come out of the neck of the balloon.

In 1934, Captain Frank Whittle of England's Royal Air Force wondered if Newton's third law of motion could be applied to airplanes. He built an engine. It consisted of three main parts: a *compressor*, a *combustion chamber* to burn kerosene, and a *gas turbine* (Fig. 313).

The compressor starts the work of the engine. Like a fan, it blows the air backward and compresses it into the combustion chamber. This compressed air contains in each cubic inch hundreds of times as much oxygen as does ordinary air. Now there is let loose in the combustion chamber an explosive fuel, like kerosene or gasoline. When the mixture of kerosene and compressed air is ignited, all the hot gases swish out of the rear opening, just like the air escaping from a rubber balloon. It is the thrust of these gases that pushes jet airplanes through the skies.

313
The parts of a jet engine. How is the air compressed for explosion of the fuel in the combustion chamber?



Recent refinements of Captain Frank Whittle's design made by several of our great engineering laboratories have produced jet engines so powerful that they can drive airplanes faster than the speed of sound, beyond 750 miles per hour. Such speeds are called *supersonic* speeds.

JATO—JET—ASSISTED TAKE—OFF

Not so very long ago, there were several United States Army fliers marooned on the icecap of Greenland. A large United States Navy aircraft carrier came to their aid, battling tremendous seas. Army air forces had tried several times with planes and gliders to rescue these men.

However, a plane equipped with Jato made a landing near the men, who were living in ice caves supplied with equipment dropped from the air. With the power supplied from jets, the large airplane zoomed up into the sky, carrying the marooned men to safety.

JATO WORKS THIS WAY

Have you ever seen skyrockets fired on a Fourth of July celebration? The rearward thrust of the burning powder sends the rocket high into the air. Newton's third law of motion is applied here: For every action there is an equal and opposite reaction. The action of the Jato jet is very powerful. The result is that the plane, reacting to the rearward thrust of the jet, is catapulted into the sky on a short take-off. Thus it is that the Greenland rescue plane was airborne in an incredibly short distance.

Jato take-offs for small planes can be carried in bottles slightly larger than a thermos bottle. Compressed liquid air and alcohol, with a spark to ignite the fuel, push the plane to an altitude of hundreds of feet, in the time that a plane without this advantage rises less than 20 feet. With this assistance, a plane can fly fully loaded from a small field. On a normal flight, if the engine of the plane fails, the pilot can switch to jet and thus have power enough to find a safe landing field. No doubt, flying with large or small planes has been made safer with the application of jet-assisted take-off.

SPEED OF AIRPLANES

Since the first airplane was successfully flown at Kitty Hawk, North Carolina, by the Wright brothers early in the twentieth century, the speed of airplanes has increased from 35 miles an hour to over 700 miles an hour. Engine horsepower to produce thrust has increased from the 12 horsepower engine used by the Wright brothers to engines of almost 4,000 horsepower used today. Much of this increase has taken

place during and since World War II with jet engine planes.

Because greater speed is essential for military and commercial planes, aeronautical engineers have been continuously at work to produce faster and faster planes. At supersonic speeds, however, the conventionally designed aircraft is unmanageable. Air piles up in front instead of flying over the wings. The plane is flying faster than the wind in a tornado. But like other problems, this one is being solved, and it may be that man, entering the era of supersonic flights, will be traveling soon at over 1,000 miles per hour (Fig. 314).

THE HELICOPTER

One of the most useful planes today is the helicopter. Its "wings"—really huge propeller blades—are rotated by an engine and can be tilted in many directions. The helicopter can rise and descend vertically or hover over one spot. Think what this means in rescue work on sea or land, where survivors of shipwreck or plane crashes can be immediately evacuated! And this airplane can be made to go forward, backward, and sideways by tilting the wing blades in the proper direction.

The whirling motion of the wing blades causes a twisting motion that would make the craft unmanageable if it were not for a small propeller on the tail to counteract this motion. However, helicopters with double sets of wing blades, each whirling in the opposite direction, have counteracted this twisting motion.

THE FUTURE OF THE AIRPLANE

It is a matter of only a few flying hours now to cross oceans. Today airplanes carry millions of passengers and hundreds of thousands of tons of freight in the United States each year. Some cargo and passenger planes weigh over 100 tons and can carry 20 tons of cargo. Planes weighing hundreds of tons are on the drawing boards of large airplane manufacturers. Airports are being built or lengthened or strengthened everywhere to receive these sky monsters.

Safety controls are improving steadily. No longer is it necessary to fly "blind" in a fog or storm. The pilot has a radar picture of his landing field. He also has a radio beam to guide him in, and he can talk by radio to the control tower on the field. It is as safe today to travel by air as to travel by automobile, railroad, or steamship.

Considering the rapid advances made in the last few years in transportation on land, on sea, and in the air, no one can prophesy what the next decade or two will bring. It is safe to say, however, that the changes will be exciting.

GOING FURTHER

1 *Checking Archimedes' principle.* Tie a piece of string around a stone or a small piece of scrap iron. Weigh the stone or iron with a spring balance. Fill a jar or beaker absolutely full of water. Now weigh on the balance any small pail into which the bottom of the beaker will fit. Place the jar of water in the pail. Now with the stone attached by a string to the balance, slowly lower the stone into the water. Note the difference between the weight of the stone in air and its weight in water. How much weight did the stone seem to lose?

Remove the jar from the pail that now holds the overflowed water. Weigh the pail again and make a note of its increased weight. What is the weight of the overflowed water? Compare this weight with the apparent loss of weight of the iron or the stone in water. Is Archimedes' principle true?

2 *Flotation.* Fill a pail of water. Place an

314 *A rocket-powered experimental plane, designed for a maximum speed of 1,700 miles per hour. Already it has flown faster than the speed of sound (763 miles per hour at sea level). At a speed of 1,700 miles per hour, it could fly from New York to San Francisco in about $1\frac{1}{2}$ hours. (U.S. Air Force)*

empty tin can on the surface of the water in the pail. Does it sink? Now add weight to the tin can by dropping in pebbles or sand. Note the various levels to which the tin can sinks as its weight increases. Does it displace more and more water?

Remove the tin can, empty it, and smash it flat with a hammer, bending it over and over again. Place the battered can in the water. Does it sink? Does it displace as much water as before? What effects have size and weight in determining whether objects sink or float?

3 *Air pressure acting on a can.* Take the cap from a gallon syrup can and pour into the can one-half cup of water. Boil the water in the can for one minute. The air in the can is pushed out by the steam. Now push a cork stopper firmly into the opening in the can and remove the can with cloth holders to a nearby sink. Pour cold water on the outside. The steam condenses into water, $\frac{1}{1700}$ of its volume, and causes a partial vacuum in the can. What happens to the can? If the inside of the can were filled with air of the same pressure as the air on the outside, would anything happen to the can?

4 *Checking Bernoulli's principle.* Fold about one inch of the bottom of a sheet of composition paper. Hold the fold about two inches away from your mouth, and blow against the fold and over the top of the remaining paper. What do you conclude as to the reason for the lift given to the paper? Is Bernoulli's principle true?

5 *Building a model of an airplane.* Purchase an inexpensive kit. Identify the parts by labeling and put the model on display in the schoolroom.

6 *Words are ideas.* Can you use these words in a sentence which will give their meaning? Use the glossary.

rocket	Kingston valves	rudder
jet engine	vent valves	stabilizer
clutch	helicopter	elevator
differential gears	ailerons	airfoil
transmission	fuselage	lift
compressor	drag	thrust

7 *Put on your thinking cap.*

1. In what ways have the automobile and truck influenced life in the United States?

2. If you were to speak on the need of a safety program, what points of careful driving would you stress?

3. In what ways has the T-form of rails advanced the science of railroading?

4. Why does a ship made of steel float whereas a piece of steel sinks in water?

5. A pine log is pushed into a river. The log contains 4 cubic feet and weighs 135 pounds. Will it sink or float? (A cubic foot of water weighs 62.5 lbs.)

6. How does an airplane get lift?

7. If the drag of an airplane is less than its thrust, can the airplane fly? Explain.

8. If the lift of an airplane is less than its weight, can the airplane fly? Why?

8 *Test yourself.* In your notebook, complete the following sentences with a correct word or phrase. Do not mark this book.

1. Rockets can travel at a speed of almost ...... an hour.

2. A ...... disengages the power of an automobile engine from the rear wheels.

3. The ...... of an automobile enables it to go forward or backward.

4. Any substance floats in water when it is ...... than the weight of an equal volume of water.

5. Water pressure ...... with depth.

6. Air hammers and rock drills operate with ...... air.

7. Air pressure ...... with height.

8. Banking of an airplane is done by moving ....

9. The ...... of an airplane contains passengers and freight.

10. An airplane is turned to the right or left by moving the ....

11. An airplane is made to dive or climb by moving the ....

12. An airplane gets lift when the pressure on the upper surface of the wing is ...... than the pressure on the lower surface.

13. The angle of the wing as it meets air resistance is called the angle of ....

14. Streamlining of planes has greatly reduced ....

15. Speed beyond 750 miles per hour is called ....

16. A plane which can rise or descend vertically and travel in any direction is called a ....

9 *Adding to your library.*

1. *Up for Air* by Frank Meier, Dalton and Co., 1940. Have you ever thought you would like to be a diver? Here is a man who can tell you what such work involves —its risks, its thrills, its hazards.

2. *Coming Age of Rocket Power* by G. Edward Pendray, Harper, 1945. A detailed account of the development of rocket power and jets.

3. *Up Periscope* by David Masters, Dial Press, 1943. The operations of British submarines during World War II.

4. *Stick and Rudder* by Wolfgang Langewiesche, McGraw-Hill, 1944. An excellent explanation of the art of flying.

5. *Rockets and Jets* by Herbert S. Zim, Harcourt, Brace, 1945. An interesting book which tells the history of rockets and jets, their present and future use.

6. *Safety in Flight* by Assen Jordanoff, Funk and Wagnalls, 1941. Weather and its effect on flying.

UNIT SEVEN

STRENGTHENING THE WORLD'S COMMUNICATIONS

This is the famous Crypt of Civilization at Oglethorpe University, Georgia. In it is a record of man's achievements which is designed to give a picture of civilization in the twentieth century to men living in 8113 A.D. *(Professor T. K. Peters, Oglethorpe University)*

Waves, wire and wireless

Two Georgia professors have built a burglarproof vault which they believe will survive until the eighty-second century—until 8113 A.D.! To make sure that the scientists of the eighty-second century find this vault they have written in many languages and distributed over the world this message:

"Near a place once known as Atlanta, Georgia, there was a house of learning known as Oglethorpe University. . . . [Here careful directions are given for finding the site of the University.] If the 82nd-century scientists will dig at the specified spot, they will come upon a stone vault 20 × 10 × 10 feet guarded by a door of stainless steel. In this vault will be found writings and objects of great value, amongst them the best examples of civilization and knowledge known to the world from the time of the death of Christ to the mid-20th century."

Dr. Jacobs and Dr. Peters, who built and stocked the stone vault under Oglethorpe University, realize that 6,000 years from now no present building of ordinary construction will remain in existence. The burglarproof vault these professors have built has a good chance of survival. Inside the vault are small stainless steel models of our most useful inventions: typewriters, radios, engines, automobiles, airplanes, and so on. The two scientists were able to include several thousand books, songs, maps, and other records on film. For instance, an entire encyclopedia was recorded on film and sealed in a small can. Also in the vault are movies, film strips and different kinds of records of music and speeches.

How were these records of our civilization made?

As you read on in this unit, you will learn many interesting things: how the records which fill the "Crypt of Civilization" at Oglethorpe University, the records which are waiting 6,000 years for dis-

covery, were made; how man reached the moon with radar; how your ears can hear what is going on in London, Paris, or Rome while you sit in your living room. You will discover how voices need never die. You will learn how people centuries in the future will know how we speak, how we dress, how we eat. You will discover, in short, how man has conquered space and time by wire and wireless.

315 *These pupils are taking an audiometer test to discover how well they can hear. Some pupils do poor work simply because they cannot hear what is said in class. (Board of Education, New York City)*

CHAPTER 25

HOW WE HEAR

Some people are pretty good at listening. Take the case of the miner who was sitting in a Washington, D.C., motion picture theater one snowy afternoon. In spite of his interest in the movie, he suddenly jumped out of his seat shouting a warning of danger and ran to the nearest exit. By doing so he saved his life and those of others. Moments later the roof caved in, killing and injuring some people in the audience who had not heeded his warning.

Listening had saved the miner's life. A miner is by habit always alert for the sound of a possible cave-in, a constant danger in the mines. His ear had caught and his mind had understood the meaning of the faint noises which had preceded the collapse of the roof. Few people make such good use of their hearing equipment. Do you?

HEARING VIBRATIONS

There are easy ways to test your hearing. One is to take an audiometer (ô′ dĭ ŏm′ē tẽr) test. In one kind of audiometer test you sit down in front of a machine that resembles a radio-phonograph. You wear an earphone on each ear and all you have to do is write down the things you hear (Fig. 315). Usually you hear a voice repeating different numbers like 326 and 477 in steady succession. This voice becomes softer and softer until you fail to hear it. Your hearing is rated according to the numbers you fail to hear. You owe it to yourself to take a test of this kind. If it shows that your hearing loss is great, you should see a doctor.

TEST YOUR HEARING

Here is an informal hearing test you can try. Next time several of your friends visit you, give each of them a paper and pencil, then seat yourselves comfortably and just listen. Write down all the sounds you hear. Identify as many as you can. Limit yourselves to one minute.

When the time is up, count the number of items on your list. Compare with lists made by your friends. There will probably be some differences in the number of items listed. Individuals differ in their ability to hear even though they have the same hearing equipment.

COLLECTING VIBRATIONS

You can't see them from where you are sitting but your ears have several parts. The outer ears are visible on the outside of your head. Each of these outer ears leads to a middle ear which in turn connects with an inner ear (Fig. 316).

Normal hearing begins when your funnel-shaped outer ears help gather together the vibrations that are coming toward you from all directions through the air and cause your eardrums to vibrate very rapidly.

What are vibrations? Here are methods which will help you to see as well as hear vibrations. If you have never done so before, stretch a rubber band between two fingers and strike it with the nail of another finger. Notice the way the band moves up and down so rapidly that the eye cannot follow the movements. These movements are vibrations. Can you hear the twang of the rubber band? This twanging sound is caused by the vibrations of the rubber band. Vibrations cause sound waves in the air. When a violinist plays his instrument, he makes sound waves by causing the strings to vibrate. So does a saxophonist when he blows into his instrument. A drummer makes sound waves by causing the tight skin of his drum to vibrate. It is the air which carries these vibrating sound waves to your ear.

Sound vibrations are difficult to see. For instance, if you were to strike a tuning fork you might hear the sound but you probably would not see the vibrations except as a slight blur.

One way to see the vibration made by a tuning fork is to run a needle attached to the vibrating fork over a piece of smoked glass. The needle will make definite wavelike marks. Another way is to attach a small mirror to a violin string or to a wire held taut. Direct a beam of light from a projector or flashlight against the mirror. Catch the reflection on the opposite wall or ceiling. Now touch the wire or string with a vibrating fork or run a violin bow over it. Watch the reflected beam of light hop, skip, and jump.

LISTENING WITH YOUR BRAIN

The eardrum is a thin membrane (skinlike tissue) that separates the outer ear from the middle ear. Since it is easily damaged, it is unwise to use sharp objects to remove wax from your ears.

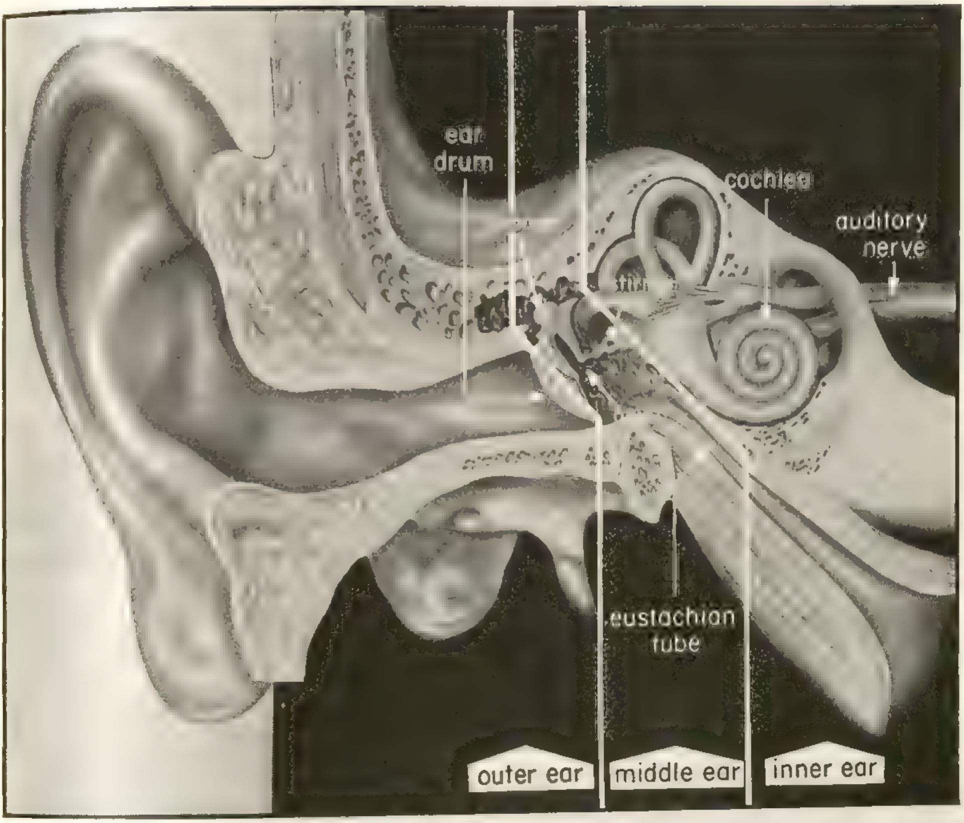
When sound waves strike an eardrum, they cause it to vibrate. This sets in motion the three smallest bones of the human body. They are called the hammer, the anvil, and the stirrup. Don't be fooled by the size of these bones as they appear in Fig. 316. Actually they are about the size of the capital letters on this page.

When these three tiny bones move, they create vibrations in a fluid in the inner ear. This fluid fills a remarkable snail-like coil in your inner ear, called the cochlea (kŏk′lē *ȧ*). In the cochlea are found fibers arranged in a way that may remind you of the strings of a piano. These fibers unite to form a nerve which reaches the brain. Nerve impulses set up by the vibrations are carried to your brain. It is the brain which interprets the vibrations as words, or music, or noise.

WHY SOME PEOPLE FIND IT HARD TO HEAR

Some people are deaf. Deafness that develops after birth usually results from an obstruction in the ear or from an injury to the nerve which connects the cochlea to the brain.

You can easily discover how much hearing loss results from an obstruction in your outer ear. First measure the distance at which you can no longer



316 *The three main parts of the human ear. Each part serves a purpose. What is the meaning of the advice, "If you scratch your ear, do it with your elbow"? (Western Electric)*

hear the ticking of a watch or clock. Then plug up your ears with soft wads of cotton or a pair of swimmer's ear plugs, and measure the distance again.

Small children sometimes put small objects such as beans or beads into their ears. Or wax may form in the passage of the outer ear. Water may collect there if you swim under water or do some diving. You may bend your head down and let the water run out, but you should never try to remove anything else from your ear if a soft wad of cotton fails to loosen it. Report any obstructions in your ear to your parents or doctor.

DISCOMFORT IN THE MIDDLE EAR

There are times when obstructions in the ear are sensible. For instance, an ear plug of soft cotton worn when you are high diving or swimming under water may save you from a broken eardrum.

How does a change of air pressure affect the eardrum? It is something like the feeling that occurs when you ride through a tunnel, when you travel in a high-speed elevator in a tall building, or when you blow your nose too hard. The temporary discomfort in such situations, however, is usually mild and easily corrected by swallowing hard.

Swallowing causes the Eustachian (ū stā′kĭ ăn) tube to open. This is an air tube leading from the back of the throat to the cavity of the middle ear. Swallowing forces the air in the tubes up against the eardrums. Thus it equalizes the pressure inside the eardrum with the pressure on the outside. It is the uneven pressure on the eardrum that causes discomfort. The Eustachian tube permits you to equalize the pressure on both sides of the eardrums. Soldiers are advised to keep their mouths open during a bombardment to equalize the pressure caused by the explosions and thus avoid ruptured eardrums. If the mouth is open the air pressure changes in the Eustachian tube at the same time as it changes in the outer ear.

Although the Eustachian tube serves us well in one way, it is also an avenue through which infections of the nose and throat may spread to the middle ear. When this occurs, you will surely have an earache. If you have an earache, go to a doctor and follow his advice. If infection of the middle ear is allowed to go uncorrected, it may result in permanent loss of hearing.

HEARING AIDS

Nowadays, most cases of deafness can be corrected by the use of hearing aids.

You are probably familiar with the old-fashioned ear trumpet which was used to catch sounds. Ear trumpets have been replaced by various electrical devices. One hearing aid has a tiny earphone like a telephone receiver (Fig. 317). It is connected to a tiny microphone and a small loud-speaker or amplifier which makes the sounds louder. A partially deaf person using this device can hear normal speaking voices.

Another hearing aid is worn behind the outer ear (Fig. 317). Here it makes contact with the bones of the skull and transmits to them the vibrations, which have been strengthened in an electric amplifier. This hearing aid is for a person whose eardrum is useless but whose inner ear and hearing nerves are in good condition.

You can easily discover that the bones of the skull are able to transmit sound vibrations to your inner ear. First, stuff your outer ears with cotton plugs. Now start an old phonograph record revolving on a turntable. Bend over it with a phonograph needle or half a toothpick gripped in your teeth. When the point of the needle or toothpick touches the grooves of the record, you will hear the recording. The bones of your skull are carrying the sound vibrations to your brain.

VIBRATIONS AND WAVES

We know that vibrating objects produce sounds. Actually, it is more correct to say that vibrating objects produce sound waves. Each vibration produces one sound wave. You are familiar with water waves. You have probably tossed a stone into a pond and watched the ripples or waves start out from the center. What is the difference between water waves and sound waves? Primarily, you can see water waves but not sound waves. Secondly, sound waves move out in all directions from the source of sound in a way different from that in which water waves travel.

To demonstrate the way a sound wave moves along, the pupils in your class may place themselves two feet apart in a long line. At a signal, the last pupil steps forward until he touches the pupil ahead of him. Then he steps backward to his original position. Each

pupil in turn does the same thing, starting forward when he feels the contact of the pupil behind him, then he too returns to his original position. This is the way a sound wave moves (Fig. 318).

Actually it is the molecules in the air which move back and forth. Thus imagine that each student is a molecule. Each molecule moves forward and is pushed against another. This molecule in its turn pushes against another. Once each molecule has pushed against its neighbor, it returns to its original place much as the students did. Thus sound waves are a series of forward and backward movements of the molecules in the air. This is how the vibration moves on from its starting point.

SOUND VIBRATIONS YOU CANNOT HEAR

Strangely enough, we cannot hear all sounds. Scientists have found that in order to produce sound waves which we can hear, an object must vibrate at least 16 times per second. They have also found that we cannot hear sound produced by more than 20,000 vibrations per second. With special instruments scientists have been able to measure and photograph the sounds below and above the range of the human ear.

It may surprise you to learn that bats make sounds when they fly in the night. It helps them avoid objects in the path of their flight. The bat sends out the sound and listens for an echo. Hearing none, he knows his path is clear. Hearing one, he swerves.

If you could catch a bat and tape its mouth shut, you would see how much it depends upon the sounds (soundless to us) it makes. Such gagged bats crash against objects and may be killed. Scientists call sounds beyond the range of our hearing, *ultrasonic* (ul′trȧ-sŏn′ĭk) sounds. Bats, insects, and other animals have been using ultrasonic

317 *Modern hearing aids may be worn in or behind the outer ear.* (*Western Electric*)

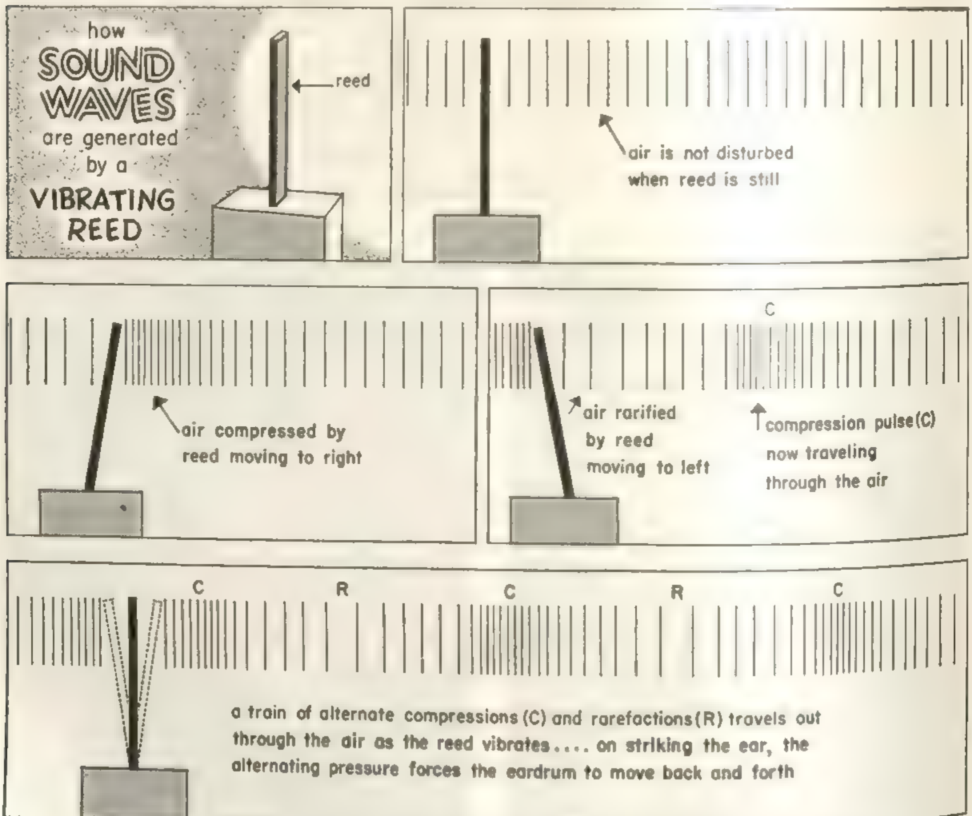
sounds for thousands of years. Man is just beginning to learn how to make use of sounds he cannot hear.

ULTRASONIC SONAR

The science of ultrasonics is very young. It was used in World War II to locate submarines. Enemy submarines had been escaping our destroyers by stopping their engines. When they lay quietly under water ordinary sound detectors could not find them. To find these submarines our navy put *sonar* (sō′när) to work.

Sonar stands for "Submarine Detection and Ranging Apparatus." Sonar can locate the position of objects beyond the range of ordinary sighting and hearing devices. Sonar sends out sound waves which bounce back when they strike an object such as a submarine. Just as a flying bat detects the presence of obstacles by the sounds which bound back, so sonar detects and identifies objects by sounds which bounce.

Sonar depends on the fact that sounds can bounce. You have probably not been aware that you have made sounds bounce too. These bouncing or reflected sound waves are known to you as echoes. Echoes are helpful when one is hunting submarines, but usually they are annoying.



318 *The closeness of the short lines at the points marked C shows how the progress of a sound wave pushes molecules together. What would happen if the reed were to vibrate more rapidly or stop vibrating?*

ECHOES

Have you wondered why your voice sounds so peculiar when you shout into an empty barrel or into an old-fashioned well? Echoes are the reason. Have you ever noticed how difficult it is to hear what is being said in busy restaurants, some auditoriums, and even some classrooms? The difficulty may be due to echoes, sounds reflected from bare walls and ceilings.

ECHO KILLING

It is interesting to see an *acoustics* (ȧ kōōs′tĭks) expert at work. Acoustics is the science of sound. An acoustics expert is an echo killer. When he sound-conditions an auditorium, a restaurant, or a broadcasting studio, he does it by reducing the bouncing of sound waves off the walls and ceiling and into your ears.

One trick of the acoustics expert is to hang soft drapes on the walls and window frames. These materials absorb sound waves. You may have noticed that when carpets and curtains are removed from a room your voice seems louder. The clothing and bodies of people in a room also absorb sound waves. Thus actors rehearsing a play in an empty auditorium sound different from when they play before an audience.

Now here is another trick of the acoustics expert. He covers the walls and ceilings or both with a layer of sound insulation. This material is full of pores. These pores break up the sound waves that hit them so that very little of the wave can bounce back into your ears to annoy you (Fig. 319). You could test the effect of these devices by sitting for a time in a room that has been lined with sound-absorbing materials and comparing it with an ordinary room. You would find that the insulated room is the more restful. It is easier to work in such a room because most of the echoes have been prevented.

319 *The ceiling of this room absorbs sounds because of the small holes in its surface.* (Celotex Co.)

HOW DO SOUNDS TRAVEL?

There is one place where you would not be disturbed by echoes, or for that matter by any sounds. You may have guessed from your earlier reading that this place might be the moon. The moon has no air to carry sounds.

Other objects or materials can carry sound too. You have already seen how the bones of your head carry sounds. If you were to put your ear against a metal pipe and listen while someone placed a vibrating tuning fork against another part of it, you would hear the vibrations. You will conclude that solid substances can transmit sound.

To test the ability of water to transmit sounds hold one ear below the surface of some convenient body of water. Ask someone to assist you by

striking two stones together under the water. You will discover why it is possible to hear underwater sounds. Underwater test explosions have been heard as far as 3,000 miles. Table IX shows you with what speed sound travels through various substances. From this table, can you tell whether you would hear a sound faster if it were carried by air, water, wood, or metal?

Table IX. VELOCITY OF SOUND

(Speeds are approximate at 20° C.)

		Feet per second
In Solids	Copper	11,670
	Iron	16,820
	Lead	4,025
	Silver	8,550
In Liquids	Water	4,800
	Alcohol	3,890
In Gases	Air	1,130
	Air (0° C.)	1,090

SOUND AND STORMS

You can make use of these facts about sounds to discover some important things. For instance, you can find out how far away an approaching storm is from you. You know that there are lightning flashes in a thunderstorm. After the lightning, you hear the thunder. Since lightning is the cause of the sound of thunder, the length of time between the lightning and the sound of thunder shows the distance the lightning is away from you. You see light almost instantaneously, while sound travels much more slowly. Light travels at the rate of about 186,000 miles per second, while sound travels in air at about 1,100 feet per second at normal temperatures.

Let us suppose you see lightning. At that instant you look at your watch. Five seconds later you hear thunder. How far away is the lightning? Well, since sound travels in air at 1,100 feet per second and it took five seconds after the lightning for you to hear the sound of thunder, the lightning was $5 \times 1{,}100$ feet away or 5,500 feet (a little over a mile).

In the same way, soldiers can estimate the range of an enemy firing at them by timing the interval between the flash and the roar of the gun. You can do the same thing while watching not too distant fireworks. If you have seen newsreel pictures of the atomic bomb tests at Bikini, you may remember there was an interval of several seconds between seeing the explosion and hearing its roar.

THE NATURE OF SOUND

From experiments you have read and done you now know the following facts about sound.

1. Vibrating objects produce sound.
2. Sounds travel in waves.
3. Our ears can detect sounds of objects vibrating between 16 times and 20,000 times a second.
4. Some sounds we cannot hear.
5. Sounds which bounce back, or are reflected back, are called echoes.
6. Sounds travel at different speeds through different substances.

VIBRATIONS YOU MAKE

How do you make the different sounds which produce speech and song? After all, it is speech which has been responsible for much of man's advance from savagery to civilization. Without speech, man would still be depending on sign language. The ability to make many different sounds made it possible for man to develop language, one of

the most important tools of his civilization. Read the last sentence aloud. How did you produce the sounds which you recognize as words?

YOUR VOICE

Obviously if you can make sound it must be that within you something vibrates rapidly enough to produce sound. Sound is produced in your voice box, also called the *larynx* (lăr′ĭngks). If you could look into the larynx, you would find your vocal cords; they look like flat folds or bands (Fig. 320). Place your hand lightly on the larynx just below your Adam's apple. Read the words in the next sentence aloud. Can you feel the vibrations of your vocal cords?

The vibrations occur when the air from your lungs rushes past the vocal cords. In ordinary breathing your cords are wide apart (Fig. 320). But in speaking and singing the cords are close together and air is forced across them, causing them to vibrate.

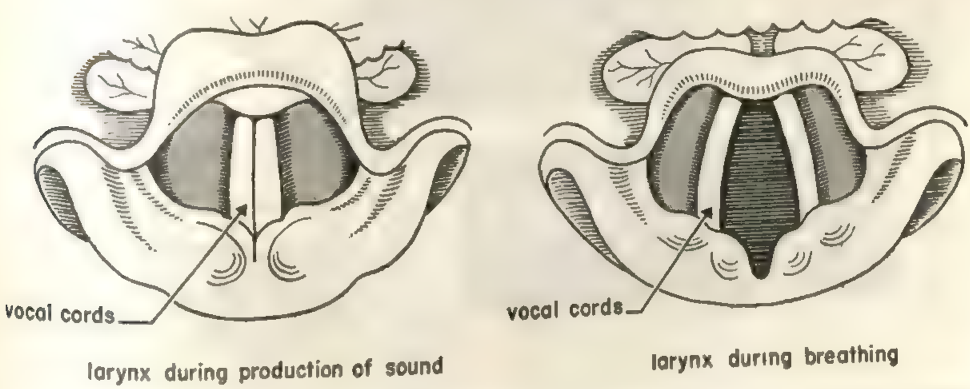
If that were all there is to speech and music, it would be a very simple story indeed. But you also know that very few voices are alike.

HOW SOUNDS DIFFER

One good way to study sounds is to try to see the sound waves which are produced by them. We can see sounds if we talk or sing into a microphone which is attached to a device called an *oscilloscope* (ŏ sĭl′ô skōp). This apparatus changes sound waves so that they appear on a screen in the form of the curvelike waves you see in Fig. 321.

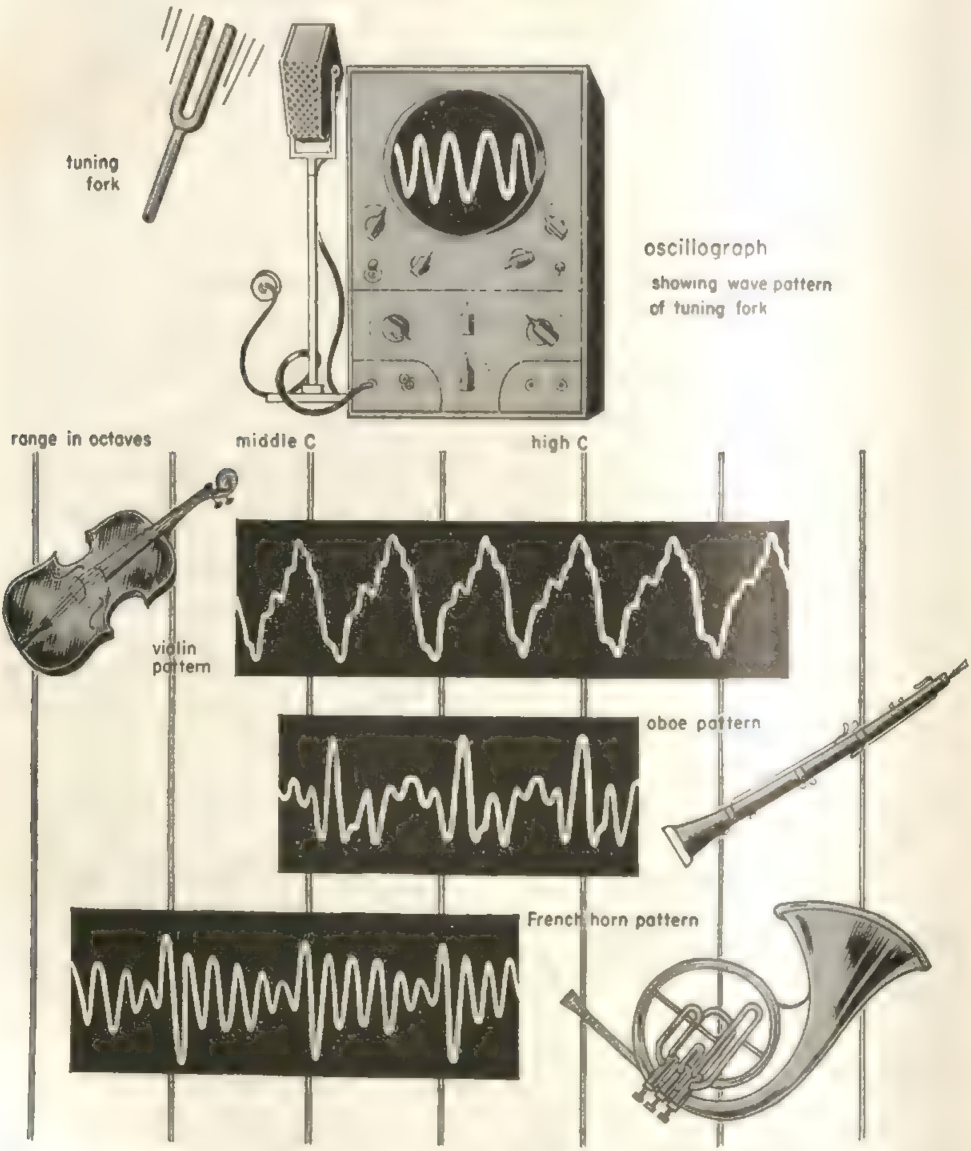
Now suppose you were to sing *do re mi fa sol la ti do* into the microphone of the oscilloscope. The waves which are caused by the *do* would have a certain pattern. If you kept singing *do* for a few moments you would find that all the waves would look like the first one. And if you could count them, you would find that the same number of them occurs in each second. For instance, middle C (*do*) on the piano produces 256 sound waves per second. The number of sound waves per second is called the *frequency*. Frequency determines the *pitch* of a sound.

Now sing the musical scale again. What is the difference between the first and the last *do*? You know that the second *do* is of a higher pitch than the first. If you were singing into a micro-



320 *Sixteen delicate muscles control the tension of the vocal cords during the production of voice sounds. Air from the lungs forced past these cords causes them to vibrate and produce many different sounds.*

phone connected to an oscilloscope you would discover that the higher *do* produced more sound waves per second. The frequency of the higher *do* is greater than the first. In other words, the more vibrations per second, the higher the pitch; the lower the pitch, the lower the number or frequency of vibrations. You can see, therefore, why some voices differ in their frequencies. A soprano, for instance, sings at a higher frequency than does a deep bass.



321 *Musical sounds are produced by vibrations with regular wave patterns. Noise has no regular wave pattern. Can you discover from this chart the range in octaves of the three musical instruments?*

Deep voices have lower frequencies than do high voices. The term frequency, you observe, stands for frequency of vibrations. Since each vibration produces a sound wave, frequency also stands for the number of sound waves produced in a second.

PITCH AND AMPLITUDE

Do not mistake pitch or frequency for loudness. Pitch depends on the number of waves per second. Loudness, scientists have discovered, depends on the strength of the sound waves. For instance, two sounds of the same pitch can be low (as in a lullaby) or loud (as in a trumpet call). On the oscilloscope a loud sound has a higher wave picture than a low one. Loudness, therefore, is indicated by the height of the wave, or its *amplitude* (ăm′plĭ tūd). The greater the amplitude, the louder the sound. Thus, the pitch of any sound you make will depend on its frequency, and the loudness upon its amplitude.

QUALITY OF VOICE

Voices can differ in quality as well as in loudness and pitch. Some voices are husky, others are brassy, harsh, or soft, depending in part on the kind of larynx a person has, on the thickness of his vocal cords, and on the size and shape of his air passages. In other words, the quality of your voice depends on the kind of voice instrument you have. For instance, a saxophone and a horn may produce sounds of the same pitch (frequency) and loudness (amplitude). But the sounds are different in quality because the instruments are made of different materials and in different shapes. Voices likewise differ because people's vocal organs differ. When you remember that the mouth, tongue, and teeth also help in producing sounds, you begin to see why sounds of the same frequency and amplitude produced by you and your neighbor may still be different. Voices also differ in *resonance* (rĕz′ô nǎns).

RESONANCE

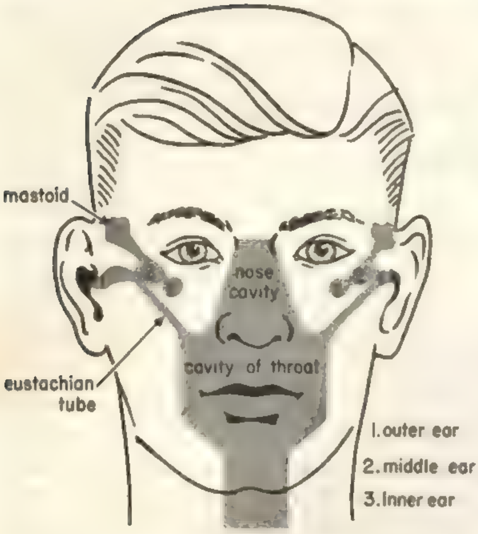
To demonstrate how sound can be made louder strike a tuning fork. Listen to it. Now strike it again and hold it against a door. Again listen. You will notice that the sound appears louder and fuller.

If you could have delicate instruments attached to the door for measuring vibrations, you would find that the whole door is also vibrating. The door is really vibrating in sympathy with the tuning fork. A violin's sound is due in part to the resonant quality of the air in the box. A Stradivarius violin is prized because of the resonance produced by its box.

What part of you has this resonating quality? Your skull has in it cavities called *sinuses*. Any sound that you make causes resonance in these cavities. Actually, it is not only the bones surrounding the sinus which vibrate in sympathy, but also the air in it. Your sinuses and other parts of your skull are resonant. That is what is meant when someone tells you that you have a resonant voice. Your voice loses parts of its resonance when you have a cold and fluids fill up passages to the various cavities (Fig. 322).

SENDING THE VOICE AFAR

From this chapter, you have learned how you make sounds and what sounds are. Using the voice in speech is the simplest way people communicate with each other. The distance through which people can communicate with each other by the voice alone depends upon the amplitude of their voices. But the human voice does not reach far.



322 *To speak pleasantly you must really use your head. Your brain controls what you say, and the air passages and bones in your skull give resonance to your voice. Why does a cold in the head usually change the sound of a person's voice?*

Your voice alone would not permit you to communicate ideas to anyone who is a great distance away from you. Our modern world-wide society is held together by man's ability to send his ideas to distant places.

Strangely enough, the inventions which enable man to send his ideas to all corners of the earth depend only in part upon the use of sound waves, but mainly on the use of various waves that travel with the speed of light.

Can light waves help transmit your ideas? Yes. And the next chapter will show you how man's ideas can travel with the speed of light, 186,000 miles per second.

GOING FURTHER

1 *Making a string telephone.* Make a string telephone by punching one small hole in the center of the bottom of two round paper containers of the type used for ice cream or cottage cheese. Push a thread or thin string 25 feet long through these holes and knot the ends. Hold one container to your mouth and talk while a friend holds the other container to his ear and listens. Be sure to hold the string stretched taut and do not allow it to come in contact with your fingers or anything else which will dampen the vibrations.

2 *Musical glasses.* Make a set of musical glasses or bottles. You will need at least eight of the same kind. Add various amounts of water to all but the first until you have tuned them to the musical scale of a piano. If you use bottles or test tubes, you can play them by blowing across the tops.

3 *Absorbing sound.* Take as many wooden boxes of the same size as you need. Set them all on the same surface after you have prepared them according to some of the following suggestions (use materials which are easily available): Paint the inside of one box, plaster the inside of another, line another with paper, line another with cloth, pad one with cotton, fasten Celotex on the inside of another. You can line other boxes with more materials if you wish. Place an alarm clock with a loud tick inside these boxes. Move back from the box till you can no longer hear the tick. Then measure the distance in feet. Which kind of treatment is best for absorbing sound? What is the value of insulating material?

4 *Words are ideas.* Can you use these words in a sentence which will give their meaning? Use the glossary.

audiometer	frequency
cochlea	amplitude
eardrum	vocal cords
wave length	hearing loss
vibrations	pitch
echo	ultrasonics
Eustachian tube	larynx

5 *Put on your thinking cap.*

1. How far away is a cliff if a man can hear the echo of his shout two seconds after he utters it?

2. Why does an orchestra rehearsing in an empty auditorium sound louder than when the audience is present?

3. Why would ordinary conversation be impossible on the moon?

6 *Test yourself.* In your notebook, complete the following sentences with a correct word or phrase. Do not mark this book.

1. Sound waves are produced by objects that are ....

2. The sounds made by animals such as bats are inaudible to us because they are ....

3. Sounds normally reach our ears as ...... which travel through the ....

4. Sounds are distinguished by their differences in ......, ..., and ....

5. Upon reaching the outer ear, sound waves set in motion a thin membrane called the ......, which in turn pushes against three tiny bones of the middle ear that are called the ......, the ...... and the ....

6. The middle ear is connected to the mouth cavity by the ...... tube which opens when we ....

7. The sounds we hear cause the fibers of the ...... to vibrate.

8. These sensations are transmitted by the ...... nerve to the brain.

7 *Adding to your library.*

1. Write to the American Society for the Hard of Hearing, 1537 35th Street, N.W., Washington, D.C., for information on devices for the hard of hearing.

2. Read *Man in Structure and Function* by Fritz Kahn, Knopf, 1943. Chapter 19 tells about the vocal apparatus. Chapter 45 tells about the ear. You can get much from the illustrations.

CHAPTER 26

HOW WE SEE

A signmaker's factory in Brooklyn, N.Y. displays this advertisement: WE MADE SIGNS BEFORE WE COULD TALK. That inscription would make a good title for a book on the history of communication.

Primitive men, who could not understand each other's speech, discovered that they could communicate ideas to each other by certain signs made with hands and fingers. As they practiced this kind of talk they developed a complete sign language. Since they could not write they developed other ways of leaving messages. Marks on trees or carefully arranged sticks and stones left on a trail told a story to those who later came upon them. Soon there were different kinds of sign languages in use. Even before Europeans first

reached this continent, the North American Indian was a master of this art of communication.

Do you realize that even the letters on this page are a form of sign language? Look at them one by one. They are not pictures such as the Egyptians once used. They are signs that we have learned to combine in ways that have meaning.

Here are some other signs:

π # $ % & Δ φ ʒ * ÷ @ ¢ ♃ ! ♆ .

How many do you recognize? Some of them have meaning to you while others may not. The point is, if you and someone else do not know the same code, you cannot communicate.

You must, of course, be able to see signs before you can understand them. You won't get very far if you try to read this page in the dark. One part of the explanation is easy to grasp: for visibility you must have sufficient light. Light, like sound, is one of our most important avenues of communication. What are the characteristics of light that make it the basis of human communication?

LIGHT WAVES

In the last chapter you learned that you could tell how far away a storm was by counting the seconds between the flash of lightning and the sound of thunder. Lightning and thunder are produced at about the same time, but the sound of thunder takes a few seconds to reach our ears after the flash of lightning appears. Light must, therefore, travel faster than sound.

SPEED OF LIGHT

In 1931, the American scientist Albert A. Michelson (mī'kĕl sŭn) was able to improve on previous methods and make a very accurate determination of the speed of light. The figure he obtained was 186,284 miles per second. For most purposes the figure 186,000 m.p.s. is accurate enough. Sound, as you remember, travels about 1,100 feet per second. Thus light travels about 900,000 times faster than sound.

LIGHT WAVES

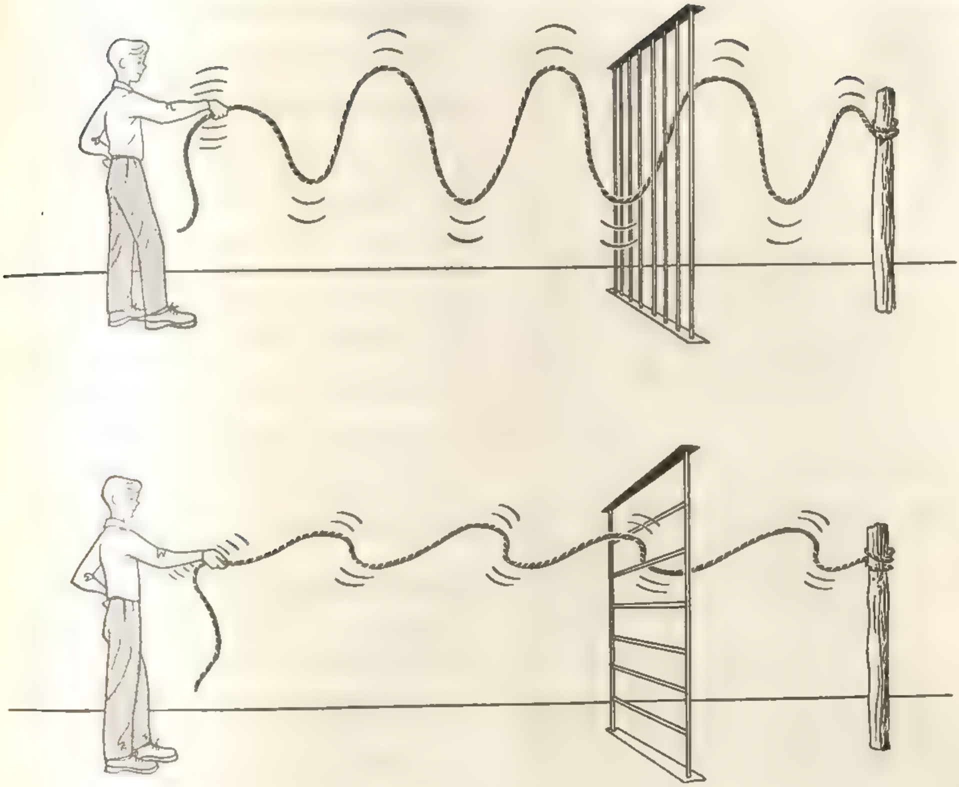
Light waves have been compared to water waves, but of course light waves travel much faster and are much smaller. About 50,000 light waves occupy only a single inch.

Light waves vibrate up and down and crosswise at the same time. A light wave is like the movement of a rope, one end of which is tied to something stationary while the other end is moved up and down or sideways. Try this for yourself and note how the movement of the rope travels like a wave from one end to the other (Fig. 323).

You send a wave along the rope in either direction, up and down or sideways. You can start a wave sideways and lift the rope up or down after the wave has started.

If you place a vertical grating across the rope you can still wave the rope up and down but not sideways (Fig. 323). Turn the grating through an angle of 90° so that the slit is horizontal. Now you can wave the rope sideways but not up and down. If you use two gratings at right angles to each other, you cannot send the wave along the rope in either direction beyond the grating.

Let's try the same experiment with light waves. By using a special filter, it is possible to keep out of our vision all light waves except those vibrating in one direction. This is called the polarizing of light. A polarizing filter might be compared to a grating with slits in it too tiny for you to see. These



323 *Light waves represented by the rope wave in the diagram can travel freely if nothing interferes. What would happen if the gratings were both used together?*

slits stop the light waves in one direction much as your grating stopped the waves produced by the rope. But you can still see through them because some light waves can come through in the other direction.

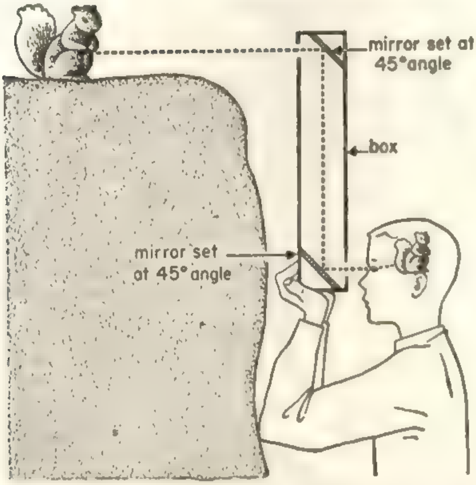
If you were to place two pieces of polarizing filter or two polaroid sun glasses at right angles to each other, you would not be able to read this page through them. Why? Think of the polaroid materials as gratings. You remember that rope waves could not go through two gratings at right angles to each other (Fig. 323). In somewhat the same way, light waves cannot go through the polaroid gratings at 90 degrees to each other.

What produces these light waves?

PRODUCING LIGHT

Light comes, you may think, only from hot objects like bonfires, burning candles, electric light bulbs, and the sun. In a sense, though, light also comes from objects such as the moon, this page, and your face. Such light, however, is reflected light that came originally from some object which was the source of the light energy. What is the source of the light reflected from this page?

In order to produce light, some energy must be used. You will remember that energy is the ability to do work. Thus when any work is done,



324 *A periscope employs two mirrors set at angles of 45° to the sides of the tube. How many times has the light been reflected by the periscope?*

you may expect that some sort of energy has been used. What kinds of energy are used to produce light? There are several listed below.

ENERGY CHANGES PRODUCED BY LIGHT

We have seen how heat, mechanical, electrical, and chemical changes can produce light. But can light itself be used as a source of energy?

Light is responsible for the food you eat (Chap. 16). The sun gives off not only heat energy but light energy as well. In photosynthesis, light energy from the sun enables green plants to make starch. And while the sunlight strikes us, some of the light energy is turned to heat energy, as anyone knows who has burned a hole in a piece of paper with a magnifying glass. Without the light energy from the sun, life would not exist on this earth.

HOW LIGHT ILLUMINATES

Before you study illumination, it is necessary for you to understand how rays of light travel. Try looking through a piece of rubber tubing about 18 inches long at any convenient source

Things to do	Energy change produced
1 Mix solution A[1] and solution B[2] by pouring them simultaneously into a gallon jug half full of water. Do this in the dark.	1 Chemical energy has produced light energy.
2 Heat a piece of magnesium ribbon in a Bunsen flame.	2 Chemical energy has produced light energy.
3 Turn on an electric light bulb. Use a neon or argon bulb.	3 Electrical energy has produced light energy.
4 Operate a friction gas lighter, a cigarette lighter without fuel, or a toy sparkler.	4 Mechanical energy has produced light energy.
5 Heat an iron nail until it glows cherry red.	5 Heat energy has produced light energy.

[1] Solution A: ¼ teaspoon lye dissolved in one pint of water. Add to this a piece of luminal the size of a cherry pit. Dissolve thoroughly. Take care not to spill the solution on your clothing. Wash with water if you do so.

[2] Solution B: ½ teaspoon potassium ferricyanide dissolved in ½ pint of water plus ½ pint hydrogen peroxide of the type purchasable in a drugstore.

of light. Do you see the light? Keep trying until you do see the light. Then observe the position of the tube. You will find that you can see the source of light only when the tube is straight. You may conclude, therefore, that light waves travel in straight lines. In other words, you cannot see around corners unless you use certain instruments like the periscope (Fig. 324). In fact, you cannot see anything (unless it is a source of light) until it is illuminated.

ILLUMINATION

When light waves strike an object they bounce off. That is, they are reflected from the object. At the moment the light waves strike an object and are reflected from it, that object becomes illuminated and visible. Illumination depends upon four things:

1. The nature of the reflecting surface
2. The angle at which the rays strike the reflecting surface
3. The strength of the light source
4. The distance of the reflecting surface from the source of light

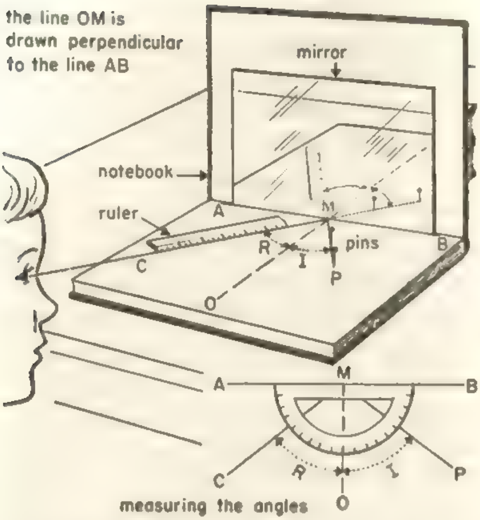
Let us look into these matters one at a time.

DIRECT REFLECTION

Look at a mirror or at any smooth or polished surface. It reflects your image directly back to you: an example of direct reflection (Fig. 325). Direct reflections have many uses in communication because they can be aimed. Signaling mirrors were used in World War II by aviators, shot down and adrift, to attract the attention of rescue planes. Mirrors have long been used in periscopes (Fig. 324). You probably can think of many other ways in which mirrors are used in communication.

A periscope requires two mirrors placed as shown in Fig. 326. Both of these mirrors are at an angle of 45 degrees. There is a reason for this as you will see when you have done the following experiment.

325 *How does the reflection in a plane mirror differ from what we see in a photograph? (Gaines Dog Research Center)*



326 *A diagram of an experiment suggested on pp. 467–68. The* (I) *incident rays of light coming from the pins* (PM) *are changed to* (R) *reflected rays* (MC) *by the mirror. The slant of these rays is always measured by the angles they form to a line* (OM) *drawn perpendicular* (90°) *to the reflecting surface.*

Hold your notebook as indicated in Fig. 326, with a mirror standing perpendicular to the flat surface. Having drawn the line AB at the base of the mirror, now draw a line along the ruler while aiming the ruler at the images of the pins which you see in the mirror (line CM). Now draw a line through the pins to point M (line PM). Finally, draw the line OM at a right angle (90°) to the line AB at the point M. You will find that you now have two angles, angle PMO and angle CMO. Even if you don't have a protractor, you may be able to see that angle PMO and angle CMO are equal (Fig. 326). But it is best to measure them.

If you look at Fig. 326, you will be able to check on the fact that the angle PMO at which the ray enters the mirror (*angle of incidence*) is equal to the angle CMO at which it is reflected (*angle of reflection*). Thus if the incident ray PM enters at an angle of 45 degrees, it will be reflected (ray MC) at an angle of 45 degrees. You may expect any ray which reaches a smooth, flat reflecting surface to be reflected at the same angle at which it entered. Test the correctness of this prediction by changing the position of the pins and measuring other angles of incidence and reflection in the way shown in Fig. 326.

You remember that light waves travel in a straight line. The light which enters the top periscope mirror tilted at 45 degrees is reflected through an angle of 90° in a straight line. Therefore, if the second and lower periscope mirror is to catch this light it too must be placed at a 45-degree angle but in an opposite position (Fig. 324).

Light is reflected intensely from the pages of a book at an angle equal to that at which it strikes the pages. You should, therefore, hold your book at an angle that will avoid reflecting too much light (known as glare) directly into your eyes. Notice how much more glare you get when your light comes from in front of you instead of from one side. For best reading or writing comfort, sit so that the light comes from over your left shoulder.

DIFFUSE REFLECTION

Diffuse reflection is produced by any surface that is not highly polished. The explanation is that rays of light striking a dull or rough surface are like tennis balls striking ground covered with pebbles. They bounce in every direction. The original direction of the rays is altered. The glossy paper used in some books and magazines is prepared by coating it with a clay product and pressing it under heavy rollers to make

it smooth. Photographs and pictures show up better on this smooth paper but it reflects a great deal of the light striking it. The surface of other book paper is rough by comparison. When the light strikes this uneven surface it is broken up, and the diffuse reflection which results is not glaring or harmful to the eyes. A book page that is not very glossy allows a diffuse reflection which does not hurt the eyes.

BREAKING UP WHITE LIGHT

Up to now we have been discussing light as if it were all of one color. From your everyday experiences you know that there are different colors. How are they produced?

Our explanation begins with the experiment performed by the famous scientist Isaac Newton at Trinity College, Cambridge, in 1666. You can repeat this experiment simply by holding a three-sided glass prism in a ray of light as shown in Fig. 327.

Newton discovered that a ray of white light is not one kind of light at all. It is really made up of different kinds of light waves, six of which can be clearly seen by your eye as different colors. Each of these colors has a different wave length. You will remember that light travels in a straight line. When it enters a prism of glass, however, the direction is changed and the light ray is bent. Each color wave is bent differently. Thus the colors found in white light are separated as the ray comes through the prism. The prism separates white light into different rays, producing a whole series of colors called a *spectrum*. In a spectrum, the light waves

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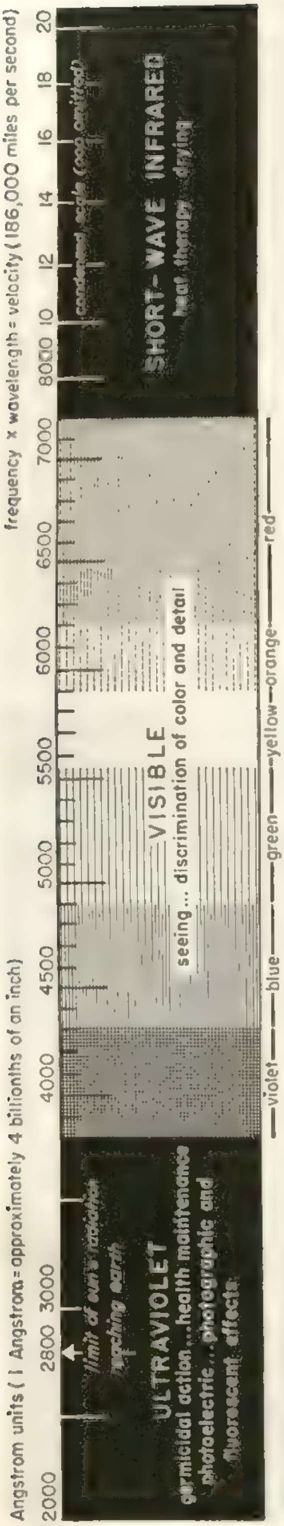
Sir Isaac Newton produced a visible spectrum by allowing a ray of sunlight to pass through a three-sided (triangular) prism of glass. Notice how the light ray is bent and spread by the prism. What similar effect is produced in nature? (Bausch and Lomb)



328
The sun's spectrum contains visible and invisible rays. Which are the invisible rays? Which are the shortest? Which are the longest? (General Electric)

are arranged from the shortest to the longest, from violet to red (Fig. 328). Light waves which produce the red color are bent the least by a glass prism. Slightly shorter waves produce orange color, then come yellow, green, blue, and violet rays. The violet rays are the shortest in the spectrum we see, the visible spectrum.

We speak of the visible spectrum to distinguish it from the invisible rays which are also a part of the spectrum of white light. Among the invisible rays are infrared (longer than red) and ultraviolet (shorter than violet, Fig. 328). These rays are also found in sunlight.

The color of an object seen by reflected light depends in part on the type of light rays it reflects. A piece of red cloth looks red because it reflects more waves of red than of any other color. Therefore, you see red. Most of the other color waves are absorbed. A green paper reflects green; it absorbs all other colors. A sheet of white paper *reflects* all colors, thus producing white. White, therefore, is really not a color but a blend of colors. On the other hand, a sheet of black paper *absorbs* all wave lengths. Black, too, is not a color but the absence of color. Grays are produced by mixtures of white and black. Notice how many shades of gray there are. Can you account for these variations?

HOW ILLUMINATION IS MEASURED

The amount of light coming from any source is compared to the amount from a candle. Not just any candle, but one prepared carefully according to certain standard directions. The amount of light this standard candle gives is called one *candle power*.

Now that you know something of the way light is produced, how it is re-


329 *Poor illumination* (left). *Notice how the shadow of the girl's hand falls on her work, decreasing illumination. Improved illumination* (right). *Assume a similar position and notice where the shadows fall. Is glare reduced by holding the book in this position?* (*General Electric*)

flected, of what it is composed, you are ready to understand how to use it best. A point one foot away from a one-candle-power source of light is said to receive one foot-candle of illumination.

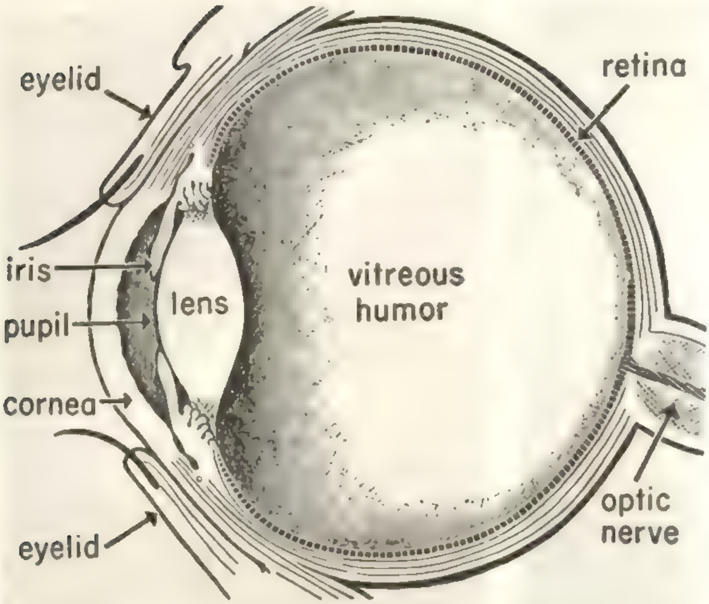
Outdoors on a bright, clear day at noon the brightness of sunlight may be more than 10,000 foot-candles, far too much for comfort. Therefore, we wear sun glasses. Under a shade tree, the illumination may be 500 foot-candles. In a theater aisle, the illumination may be only 2 or 3 foot-candles. For ordinary purposes, 10 to 20 foot-candles is desirable. For comfortable reading, about 25 foot-candles is desirable. Occupations such as sewing and engraving need a much higher level of illumination. You ought to be certain that you get proper illumination for the work you do. How can you judge what good illumination is?

HOW TO OBTAIN PROPER ILLUMINATION

Proper illumination can be judged best by the results you want to get. A subject to be photographed is not properly illuminated unless the picture produced has enough detail in light and shadow and is artistically pleasing. A room is not properly illuminated for work or reading if the people in it suffer headaches and eyestrain (Fig. 329).

You can use the following general rules to guide you as you investigate how well your own surroundings are illuminated.

1. Judge a lamp by the way its light is directed rather than by its brightness. Is its light directed at the spot you want illuminated? As you have just read, a 100-watt shaded lamp (see below) will give you about 25 foot-candles two feet away.



330

The human eye, with its main parts, in cross section. Light enters through the opening, called the pupil, in the iris. The vitreous humor is a transparent jelly-like substance that fills the eyeball and helps maintain its shape.

2. Is the light steady or flickering? The light should be steady and the illuminated object should also be held steady. Reading on moving trains or other vehicles causes eyestrain because of the flickering lights and unsteady papers and books.

3. Avoid glare caused by unshaded lamps and reflection of light directly into the eyes.

4. Use light where it is needed most. But provide enough general light so that the rest of the room is not much darker than the spot at which you work.

5. Light for reading and writing should come over one side or shoulder. In this position your head and hands will not cast shadows over your book or paper, and glare will be reduced.

6. Examine existing fixtures and lamps. Dirt should be removed from globes. Blackened electric light bulbs should be replaced.

The foregoing are good rules to follow if you want your eyes to do their best work. You will appreciate these rules all the more after you learn how your eyes react to light.

SEEING

Light becomes sight through the cooperation of the eye and the brain. The eye is a remarkable structure.

An eye consists first of the apparatus for sight: the eyeball, the socket in which the eyeball moves, and the muscles and nerves that move the eyeball. Second are the maintenance parts: the blood vessels that keep the tissues nourished, the eyelid with its lashes, and the tear glands. Finally, there are the nerves which connect the eye to the brain. Of these units only certain parts of the eyeball are helpful in changing light to sight. Do you know what they are?

FROM LIGHT TO SIGHT

Let's follow a ray of light as it reflects from this page and enters your eye. First, the ray goes through a transparent shield called the *cornea*

(Fig. 330). (A material is transparent if you can see through it.) The cornea is kept clean by the regular movements (blinking) of your eyelid. Your tear glands supply the necessary cleaning fluid.

From the cornea the ray goes through an opening in your eyeball called the *pupil*. The pupil is a hole in a doughnut-shaped screen of muscle tissue called the *iris* (ī′rĭs). The iris is usually colored blue, brown, gray, or some shade of these colors.

Look at your own pupils in a mirror. Are they large or small? Make the room as dark as possible. Wait 30 seconds to one minute. Then turn on a dim light and again examine your eyes. The pupils will be larger. The muscle in the iris makes the pupil smaller in bright light and larger in darkness. Thus your eyes are protected from light that is too strong.

The light ray passing through the pupil strikes the *lens* of your eye. The lens focuses the light ray upon the sensitive *retina* (rĕt′ĭ nȧ, Fig. 330). The retina consists of a great number of sensitive cells in the shape of rods and cones. These cells are sensitive to color as well as to light. The retina is attached to a large nerve, the optic nerve, which enters your brain. And it is your brain which interprets what you have seen.

SOME COMMON DEFECTS OF THE EYE

Any structure as delicate as the eye may have a number of things go wrong with it. The sooner you can recognize that there is something wrong, the sooner it can be treated by an eye specialist.

A frequent annoyance is an eyelash or a speck of dust getting under the eyelid. If such an object clings to the underside of the lid, it can usually be removed gently with the tip of a moist cotton-covered swab. If the object is on the cornea, or if the object is embedded in the lid, a doctor should remove it.

331 (Top) *Farsightedness is caused by an eyeball that is too short; accordingly the lens does not focus images on the retina. Why is the wearing of eyeglasses restful to a farsighted person?* (Center) *A convex lens helps the farsighted eye to focus images clearly upon the retina.* (Bottom) *Nearsightedness is caused by an eyeball that is too long. The lens does not focus images on the retina. What kind of eyeglasses does a nearsighted person have to wear?* (*Bausch and Lomb*)

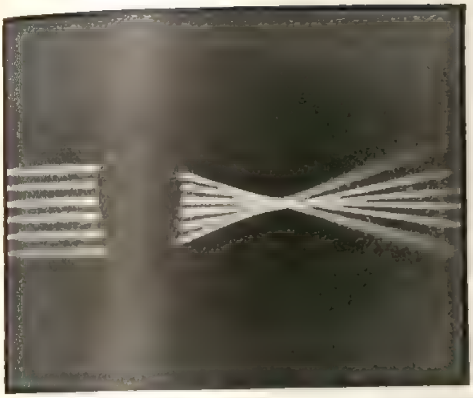
332 *Top to bottom: To a nearsighted passenger in the back seat, the boy seems indistinct, the driver clear; to a farsighted passenger, the boy seems clear, the driver less clear; a passenger with astigmatism has a distorted view of the entire scene; a passenger with normal vision has a clear impression of the entire scene.* (*Better Vision Institute*)

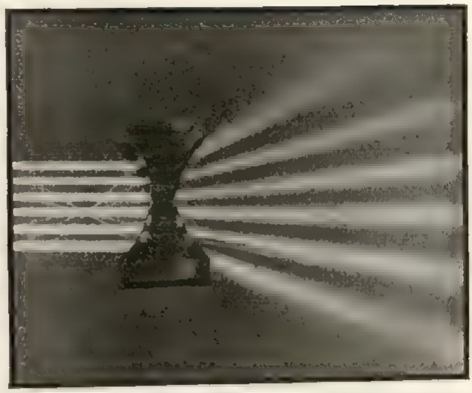
What about faults in the eye which interfere with good vision? In order for you to see correctly, the light rays from any object must focus exactly on your retina. Light rays come to a focus when they meet in a sharp point on the retina as in Fig. 331 center. Light rays on the retina are said to produce an image. Thus in Fig. 331 center a sharp image will appear on the retina.

A person whose eyeball is elongated just enough to permit the rays of light to be focused on his retina has normal vision. If his eyeball is too elongated, the image will be focused in front of the retina and therefore will be indistinct. Such a person is called *nearsighted* because only those objects held close to his eyes are focused sharply (Figs. 331 bottom, 332 top).

On the other hand, if a person's eyeball is not elongated enough, the image will be focused back of the retina. When this is the case the image will be focused sharply on the retina only when the source of the light is at a distance. That is why such a person is called *farsighted* (Figs. 331 top, 332 second from top).

If you have a reading lens at home, you will be able to get an idea of the way nearsightedness or farsightedness is treated. The effects of a blurred image can be reproduced by moving the lens too close to your eyes. A sharp image is secured when the lens is moved to the proper position. Then the object you are looking at is in focus. Unfortunately, the lens of the eye cannot be moved forward or backward without injury. Furthermore, its curvature can be changed only very slightly. Therefore, some other way has to be found to correct the defects of nearsightedness and farsightedness. To understand this you





333 (Left) *A convex lens brings light rays to a sharp focus. What type of defect in vision will this type of lens correct?* (Right) *A concave lens spreads light rays apart. Why do nearsighted persons wear eyeglasses with lenses of this type?* (*Bausch and Lomb*)

will need to know how light is affected by lenses.

HOW LENSES BEND LIGHT RAYS

When you performed Newton's spectrum experiment, you saw how rays of light were bent by a glass prism. Now notice what happens when you place two glass prisms base to base and you project a beam of narrow rays of light through them. The rays of light bend so that they come together.

We can replace the two prisms with one curved piece of glass. If we pass several rays of light through it as in Fig. 333 left we can see how they are brought to a focus. This lens is called a convex (kŏn′vĕks) lens. It makes the light rays come together, or converge. The point where the light rays meet is called their *focus*.

Suppose you turn the two prisms so that they now rest edge to edge. Notice that the light rays are now spread apart as they go through the glass. A lens of similar shape (wide at the edges and narrow in the middle) will also spread light rays (Fig. 333 right). This type of lens is called *concave* (kŏn′kāv). Its sides are hollowed out.

HOW LENSES CORRECT VISION

The lens of your eye is a convex lens. It is elastic. This means that it can change its shape slightly and become more convex or less convex. In this way, you can focus sharply on things that are a few inches away from your eye and on things that are miles away. Try focusing your glance on objects at various distances. You will note that you bring objects close to you or far from you into clear focus instantly. The lens of your eye changes its shape quickly.

Wonderfully flexible as it is, the elastic lens of the eye is not elastic enough to overcome extreme nearsightedness and farsightedness all by itself. Therefore, we help the eye by wearing glass lenses of the right kind. What kind of lens would you prescribe for a farsighted person? Concave or convex?

You will recall that a farsighted person's eyeball is not elongated enough (Fig. 331 top). We must bring the rays to focus on the retina by moving the point of focus of the light rays nearer to the lens. This can be done by giving him a convex lens to wear.

Now what about the nearsighted

person? His eyeball is too elongated (Fig. 331 bottom). We must move the focal point away from the lens (back toward the retina). This can be done by spreading the rays a bit with a concave lens. If you are curious to see the effects of these lenses upon your own vision, borrow a pair from a person who wears glasses. Then examine the lens and discover whether it is convex or concave.

You may have seen older people who need two pairs of eyeglasses, one for reading and close work, one for distance.

These people have lost the elasticity of their lenses; that is, their lenses don't change quickly enough when they examine objects close to them and then shift to objects far away. Therefore, they wear certain lenses when they are examining objects near them in reading, and others when they are looking far away as in driving. Ask such a person to show you both sets of eyeglasses that he wears and compare them.

LENSES AND THE INVISIBLE

Lenses have not always been known. Until the year 1289 or thereabouts, thousands of nearsighted persons had never seen the clouds, the stars, or the horizon. Then the invention of lenses in the thirteenth century brought these things within the range of the nearsighted people. When you stop to think of it, we all have limited vision. There are nine planets, but Uranus, Neptune, and Pluto are invisible to the naked eye. There are thousands of corpuscles in a tiny drop of blood but no man can see them without a microscope. Until the invention of the telescope in 1608 and the invention of the microscope at about the same time, men could not see distant stars nor could they see the cells in their bodies.

USING YOUR EYES

Have you tested your eyes recently with a Snellen Eye Chart? If the test shows that you have keen vision, it means that the cornea, lens, retina, and other structures in your eye are working efficiently. But it does not mean that you use your good eyes well.

For example, this book is made so that your eyes have the least trouble in reading. Notice that the print is large and clear. Also there are different kinds of type used to emphasize new words and headings. Furthermore, by using a table of contents and an index the publishers of this book have tried to make sure that you won't miss anything important.

SEEING AND OBSERVING

Unfortunately, in life there is no one to give you the kind of help you need for seeing everything you should. Have you ever gone on a field trip with a trained woodsman? Have you noticed how he sees animals and plants, tracks and signs that you have missed? You may well wonder how he does it; yet you may have better eyesight than he.

He has trained his eyes to observe wildlife. He not only sees; he observes. The observer uses his eyesight carefully; he does not glance at things hastily. He thinks about things he sees.

A scientist must be a good observer. He must be able to describe accurately what he sees. But he becomes a good observer only after long practice. He learns to examine things slowly, to ask himself, "Have I seen everything I should see?" Then he looks again. Good observation is the backbone of science and of good thinking.

It is also true that the wisest people are good observers, whether they are scientists or not. To observe means to

see well, but it also means to interpret accurately what you see.

How good an observer are you?

GOING FURTHER

1 *Experimenting with light.*

1. Put a pencil in a tumbler half full of water. Observe the appearance of the pencil from various angles. Explain what you see.

2. Fit a mask into the head of a flashlight so that only a thin ray can come through. Then in your classroom fill an aquarium tank with water and add a little milk to make it cloudy. Now darken the room and direct the ray of light into the water from various angles. Note the results.

3. Spin a top, equal portions of which have been painted with colors of the spectrum. Note how the colors blend.

2 *Dissecting an eye.* Obtain the eye of a steer from a butcher. Dissect it and attempt to identify each portion. Remove the lens, and by mounting it in a cardboard box attempt to take a photograph with it (see p. 510 for description of pinhole camera).

3 *Testing your eyesight.* Obtain an eye chart and with it test your own vision and that of your classmates. Set it up in your classroom at the usual distance of 20 feet.

4 *Indoor photography.* For those of you who have cameras and lighting equipment, photography is an excellent method of experimenting with light. As a matter of fact, good lighting is essential for good pictures. Select an indoor scene and photograph it several times.

1. Increase the illumination, doubling the candle power each time.

2. When using the best possible illumination, take photographs using different lengths of exposure.

3. Photograph a scene using front, side, and back lighting and various combinations of these.

5 *Outdoor photography.* Take three photographs of an outdoor scene with objects in the foreground, middle ground, and background. First set the focus at infinity, then at 15 feet, finally at the closest range. Adjust the speed to suit the light conditions. Which photograph has the sharpest outlines?

6 *Words are ideas.* Can you use these words or phrases in a sentence which will give their meaning? Use the glossary.

angle of incidence	lens	diffuse reflection
angle of reflection	focus	luminous
concave	foot-candle	periscope
convex	glare	polarized light
cornea	iris	
retina	spectrum	

7 *Test yourself.* In your notebook, complete the following sentences with a correct word or phrase. Do not mark this book.

1. Light is a form of ...... that travels in ...... lines.

2. The speed of light was determined by ...... to be about ...... miles per second.

3. The speed of a light wave is much ...... than the speed of a sound wave.

4. The longest visible light rays are ...... in color and the shortest of these rays are ...... in color.

5. Light rays reflected into the eye enter through an opening called the ...... and are bent by a ...... so that they are focused on the ....

8 *Adding to your library.*

1. Send for the pamphlet *Living with Light* published by the General Electric Company.

2. For information on seeing, write to the Better Vision Institute, 630 Fifth Avenue, New York 20, N.Y.

3. Consult the Boy Scout Merit Badge booklet on signaling. You can get this from Boy Scouts of America, 2 Park Avenue, New York 16, N.Y.

CHAPTER 27

WIRE AND WIRELESS

Shortly after five o'clock on the afternoon of April 3, 1860, Johnny Frey rode out of St. Joseph, Missouri. He was using his spurs and his horse really raced over the trail. Farther west Bill Cody and other riders of the Pony Express were waiting their turns in relay to carry the precious saddlebags. In these saddlebags were 15 pounds of messages destined for delivery to Sacramento, California. Ten days later, as advertised, the delivery marked a great moment in the long history of communication. The first trip of the Pony Express had spectacularly shortened the running time for the 1,956 miles between the Midwest and California.

Johnny Frey and Bill Cody and the other strong-hearted riders for the Pony Express probably never heard of an ancient Greek named Herodotus (hē rŏd′ō tŭs). Yet Herodotus might have been writing about them when he said, "Neither snow, nor rain, nor heat, nor gloom of night stays these couriers from the swift completion of their appointed rounds." This quotation has appropriately been placed on the front of the main post office in New York City.

To communicate swiftly with others has always challenged the man with an inventive mind. The jungle tom-tom, the smoke signals of the North American Indians, the beacon fires of the ancients, the semaphore telegraphs of Napoleon's time, the Pony Express, all were created and used to speed up communication between men.

It was Stephen Gray and Granville Wheeler who succeeded in sending electricity through 886 feet of wire in the year 1730. Looking back, you would think that in another six years someone would have invented a simple practical telegraph. Why then did it take 106 years?

Part of the answer is that in those early days scientists themselves did not communicate much with each other. Furthermore, scientific ideas can be put to work only after they have been tested in the laboratory. Many years of careful experimentation and invention were needed to solve the problems of electrical communication. You will see what some of these difficulties were as you read this chapter.

The two basic problems of all electrical communication are these: (1) What is needed to send a message

by electricity to someone at a great distance? (2) How shall the person receive the signals? The telegraph, the telephone, television, radio, and radar are, in the last analysis, merely different answers to these two main questions.

THE TELEGRAPH

The record shows that 23 years elapsed between the successful experiment of Gray and Wheeler in 1730 and the first practical suggestion for sending information along a wire by electricity. This suggestion was contained in a letter published in *Scots Magazine*. The letter was signed merely "C.M." Later the writer was identified as a Scotsman named Charles Morrison.

THE FIRST EXPERIMENTS

Morrison proposed that *frictional* electricity, which today we call *static* electricity, be sent along 26 separate wires, one for each letter of the alphabet. Morrison made use of a pith ball suspended from a string. This ball is attracted to an electrically charged rod. By having a pith ball hung at the end of each wire, it would be possible to send a message by sending charges of electricity along one wire after another. The receiver would read the message by watching the pith balls dance.

In the same year, 1753, a Swiss philosopher, George Louis LeSage, Jr. (lĕ sȧzh′), actually carried out the idea suggested by Morrison. His static electric telegraph invented in Geneva, Switzerland was the first successful attempt to communicate by sending a message over a wire. You may rig up one of these pith-ball telegraphs in your classroom. When you do build one, you will see why this method is not satisfactory for communicating messages quickly.

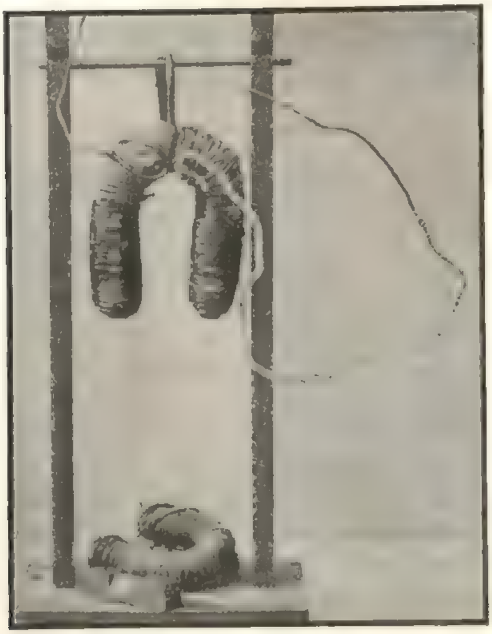
THE START OF MODERN TELEGRAPHY

Once an idea is planted it is apt to become so firmly rooted that many years may pass before it is replaced with a better idea. Many attempts were made to make better 26-wire electric telegraphs. As late as 1832 Baron Schilling invented one.

Returning from Europe in 1832, an American portrait painter named Samuel F. B. Morse received a bit of instruction in science from a fellow passenger, a Dr. Charles T. Jackson. Morse learned from him about the experiments of the great English scientist, Michael Faraday, and also about the inventions of Joseph Henry, an American teaching at the College of New Jersey (now Princeton University).

Would you like to make an electromagnet of the type Joseph Henry started working with in 1827? Just bend a piece of soft iron (a large nail will do) into the shape of a horseshoe, varnish it, wrap bare wire around it with plenty of space between the loops, and dip the whole thing into melted sealing wax or paraffin for insulation. When an electric current is sent through the wires coiled around the iron spike, the iron becomes a magnet and attracts metals. This was the best electromagnet then available.

Henry made some improvements over this type of electromagnet. First he insulated the wire by winding silk around it, a hand process that must have required great patience. Then he wound the loops of wire close together and used more than one layer of loops. Since you can obtain wire that is already insulated, it would be a simple matter for you to make several electro-



334 *Electromagnet invented by Joseph Henry in 1829. It is now in the Princeton collection of his apparatus. You can make a magnet of this type.* (*Western Union Telegraph Co.*)

magnets of the type Henry designed (Fig. 334).

The electromagnet is the basic instrument around which communication systems such as the telegraph or telephone are built. Even the electric bell, the device which tells you someone is at the door, is a simple type of "telegraph" built around an electromagnet.

THE ELECTRIC BELL, A SIMPLE "TELEGRAPH"

The vibrating-type electric bell or buzzer is such a common device that you ought to find one and examine it as you study this section. The electric bell is part of an electric circuit which can be broken at two points. The first is the push-button switch. When you press the button, you close the circuit and permit the electricity to flow along the wire. Note the thin wires. Then see how one main wire connects to the coil of the electromagnet and the other wire to the contact point of the circuit interrupter. This is a device that switches off the current just after the metal hammer or sounder (known as an armature) is attracted to the electromagnet and causes the bell to ring. Immediately after the hammer hits the bell, a spring pulls the striker back so that the contact points are brought together again. When the contact points are together, the current flows and the circuit is completed. The electromagnet again attracts the sounder and the whole process is repeated until the person ringing the bell removes his finger from the push-button switch.

You will see that the telegraph works, in a way, like the electric bell. In the telegraph, the electromagnet attracts a sounder which makes the clicking sounds heard when a telegraph is operating. But in a telegraph every movement of the armature is controlled by the sender, much as an electric gong is sounded, one signal at a time.

THE MORSE TELEGRAPH AND CODE

When Morse became interested in telegraphy, he began to work on a telegraph using the type of electromagnet Henry had perfected. Thus you see that Morse was indebted to Joseph Henry. Morse also used another of Henry's inventions, the gong-type electric bell. Fig. 335 shows how Henry rigged an armature, a bell, and an electromagnet so that when the armature was attracted by the electromagnet the bell rang. As you can see in Fig. 336, Morse used this idea of a hinged armature pulled by a magnet when he made his telegraph.

Morse sent his messages by means of a special type of switch by which the flow of electricity could be controlled.

Today, the switch is known as a key.

The instrument which received the messages was more complicated. It consisted of four main parts: an electromagnet, an armature, a stylus, and a roll of paper moving at uniform speed (Fig. 336).

Whenever current was allowed to flow through the electromagnet, the hinged armature was attracted to the electromagnet. This moved the stylus which made a mark on the moving roll of paper. The famous first message sent by Morse in 1844 said in code, "What hath God wrought?"

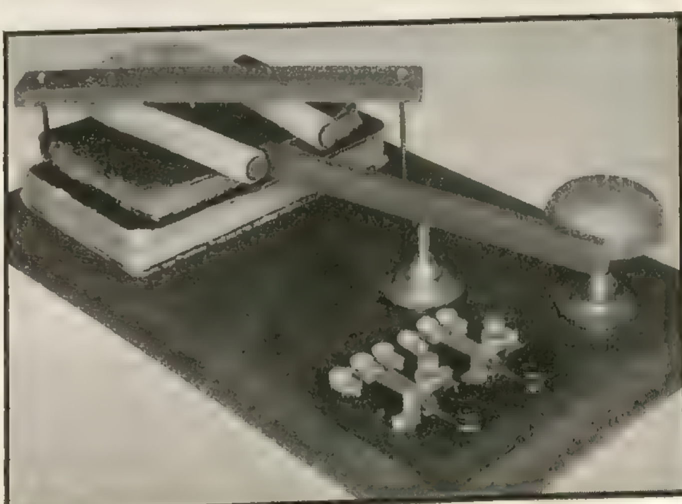
The message was sent in the code Morse had invented. It consisted of dots and dashes which were marked on the tape. Soon the operators discovered that they could receive a message merely by listening to the clicking of the armature as it was attracted to the electromagnet. This practice was frowned upon at first but soon the stylus and tape were discarded in favor of a loud clicking armature called a *sounder*. Ever since, the messages have been received by people who are trained to understand a sound code and transcribe the message by hand or by typewriter.

However, the idea of having a receiver print out the message was revived in 1855 when David Hughes of Kentucky invented a method of having the actual letters of the message printed on a tape. The telegraph messages you get today are received in this way and the tape is pasted to the message blank. Of course, the apparatus now in use is as different from the one devised by Hughes in 1855 as a modern typewriter differs from one your grandfather may have used.

THE TELEGRAPH LINES GROW LARGER

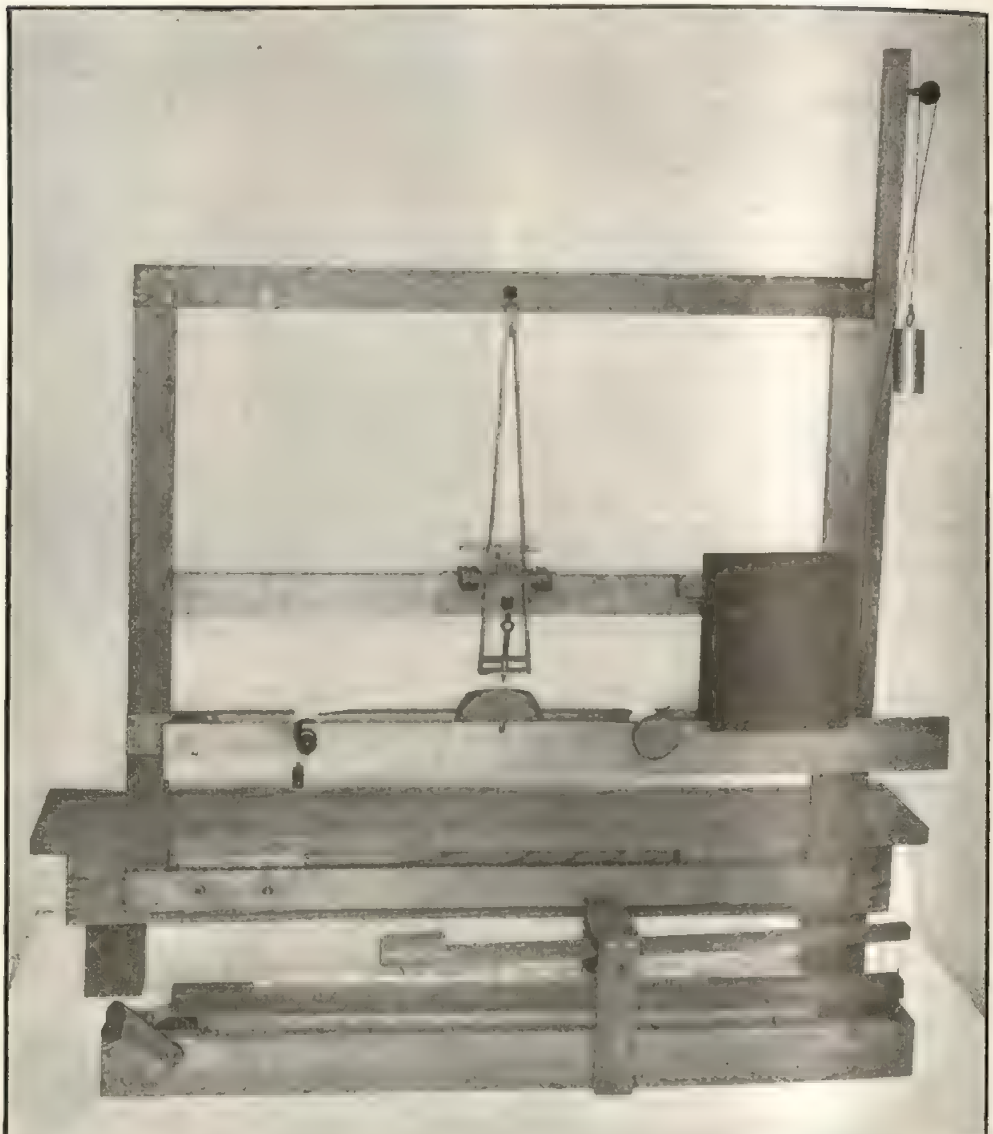
You may wonder why Morse's telegraph was so much better than some of the other earlier ones. For one thing, it was faster. More important, it could be used over greater distances because it could make use of a device known as a *relay*, another invention of Joseph Henry.

It is important that you understand the operation of a relay, for relays are used in many kinds of electrical inventions which send messages over long distances. A relay is an electromagnetic switch. It consists of an elec-



335

An electric gong invented by Joseph Henry. Notice the movable armature. (Western Union Telegraph Co.)



336 *First telegraph instrument invented by Morse in 1835. The recorder, mounted on an old picture frame, had a suspended armature to which a pencil was attached. The tape was drawn along by the works of a clock. Below the recorder is the transmitter with a row of teeth set up to produce the desired set of dots and dashes.* (*Western Union Telegraph Co.*)

tromagnet that can be operated by a very small amount of current, an armature, and contact points.

A relay is needed because a long wire cuts down the strength of an electric current. At the point where it loses its strength, a relay is wired into the circuit. The weak current is still strong enough to operate the electromagnet of the relay. As in a telegraph or electric

bell, the iron armature is attracted and moved just far enough to allow the contact points to touch. This closes a new circuit, throwing into the line new electric energy from a new source.

The invention of the relay made possible the extension of the telegraph lines across the entire continent. By October 1861, the telegraph and the railroad had put the Pony Express out of business. Those who witnessed this achievement must have thought that here was the last word in communication. Actually, it was only the beginning.

RECENT IMPROVEMENTS IN TELEGRAPHY

As late as 1910, 90 per cent of the telegraph business was still transmitted in Morse code. Now more than 95 per cent of the telegrams are transmitted and received by a device known as a teleprinter. The teleprinter was introduced in 1915. It permits the transmission of as many as eight messages at the same time over one wire. The messages are typed by operators on keyboards similar to those of a typewriter. As the keys are struck, holes are punched in a narrow moving paper tape. Letters and other characters are represented by various combinations of five holes in the tape. When the tape passes into the transmitter, metal pins slip into the holes making electrical contacts. The electric current caused by these contacts is transmitted over the wire. At the end of the wire an electric typewriter types out the message onto a tape which the operator pastes on a telegraph blank.

Another modern improvement in telegraphy is a carrier system which makes it possible to send 288 messages at the same time over a single pair of wires. Telefax is another development. With this machine a telegram, picture, drawing, or letter is put into a slot, turned on a revolving cylinder, and transmitted in much the same manner that television sends images. In addition to all these services, the telegram may be read to you over the telephone, an instrument that was not invented until after the first telegraph made by Morse had been in use for over 30 years.

THE TELEPHONE

Perhaps you have never thought of your telephone as a talking telegraph but Alexander Graham Bell (Fig. 337) thought so. His application for a patent on his first telephone in 1876 was entitled *Telegraphy.*

AT ONE END OF THE TELEPHONE

Nowadays when you telephone your friend you generally begin the conversation with a "Hello." What happens to the sound waves from your vocal cords? As you know, sound waves cannot travel for long distances over a wire. But electricity can.

The part of the telephone you speak into is called the *transmitter* (Fig. 338 left). Your telephone transmitter has an electric current going through it. In the transmitter sound waves change the electric current in your telephone. This changed current travels along the telephone wire to the receiver on someone else's telephone. There the electric current is changed back to sound waves like those spoken into the transmitter.

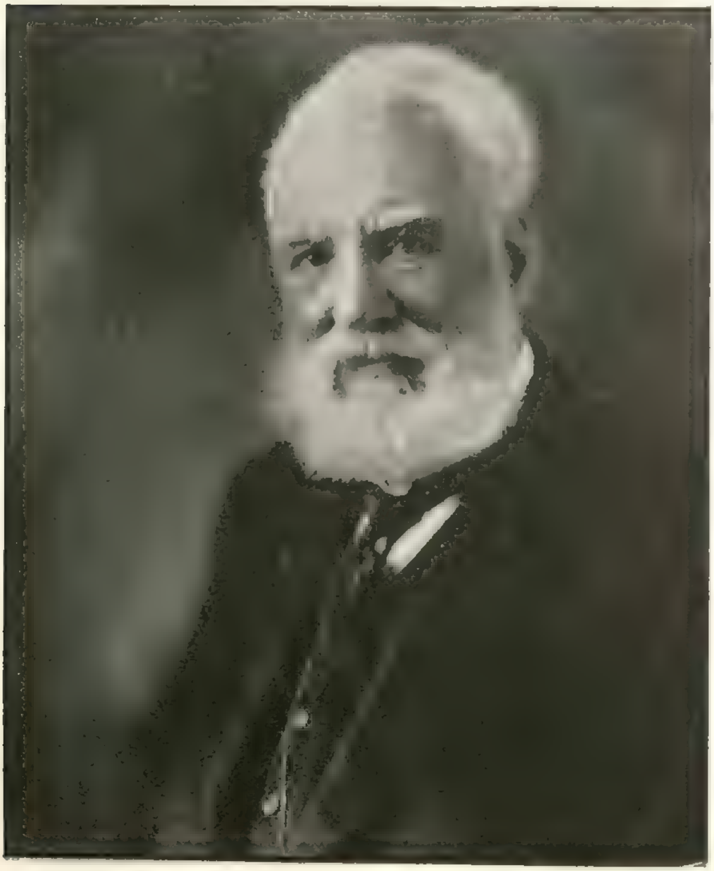
In a transmitter the sound waves from your voice box push in a thin *metal diaphragm* which is shown in the diagram. Behind this diaphragm you will find a small box of *carbon granules.* When these carbon granules are packed close together, the electric current in your telephone flows readily. When the grains are loosely packed, the flow of

the electric current is weaker. Sound waves pressing against the diaphragm act to push the carbon particles together. But different sound waves press against the particles differently. For instance, if you were to read this sentence into a telephone, the carbon particles would press and loosen up against each other thousands of times per second as the different words are read.

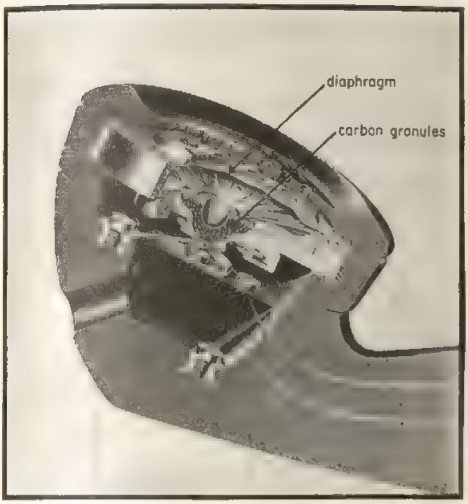
Can you see that this would result in different amounts of electric current, a kind of electrical pattern flowing through the wires? This is how different sound waves cause different amounts of electricity to be transmitted over the wires. What effect does this have on the receiver?

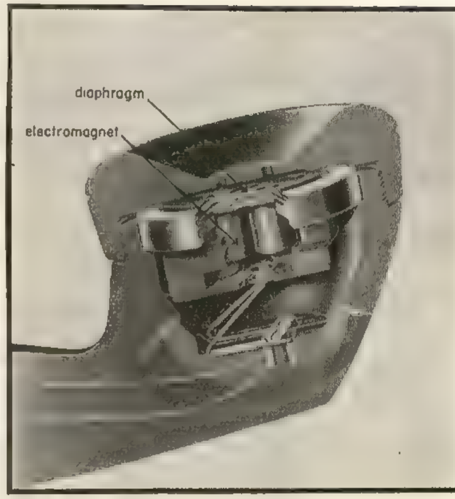
ON THE OTHER END OF THE TELEPHONE

At the other end, your friend's receiver begins to operate. In the receiver (Fig. 338 right) is another *metal diaphragm* and an *electromagnet.* As the electric current reaches the electromagnet, its magnetism will attract the diaphragm and cause it to vibrate against the air. This produces sound waves. But remember that you, at the transmitter, are not sending an even electric current along the wires to the receiver. The different sound waves you produce result in different amounts of electric current being sent along the wires. Thus the electromagnet in your friend's receiver is stronger or weaker depending on the current it gets. The diaphragm near it is attracted to



337
Alexander Graham Bell (1847–1922), the inventor of the telephone. (Bell Telephone Laboratories)





338 *A modern telephone instrument: transmitter* (left), *receiver* (right). *Describe the function of each labeled part. Which part of the telephone is similar in operation to the telegraph receiver?*

the electromagnet strongly or weakly depending on the incoming current. The result is that the diaphragm vibrates at different frequencies and produces different sounds.

Since it is your voice (producing sound waves) which causes the diaphragm in your friend's receiver to vibrate, it can be said that the diaphragm is reproducing your sound waves. This is the reason your friend hears you and can recognize your voice.

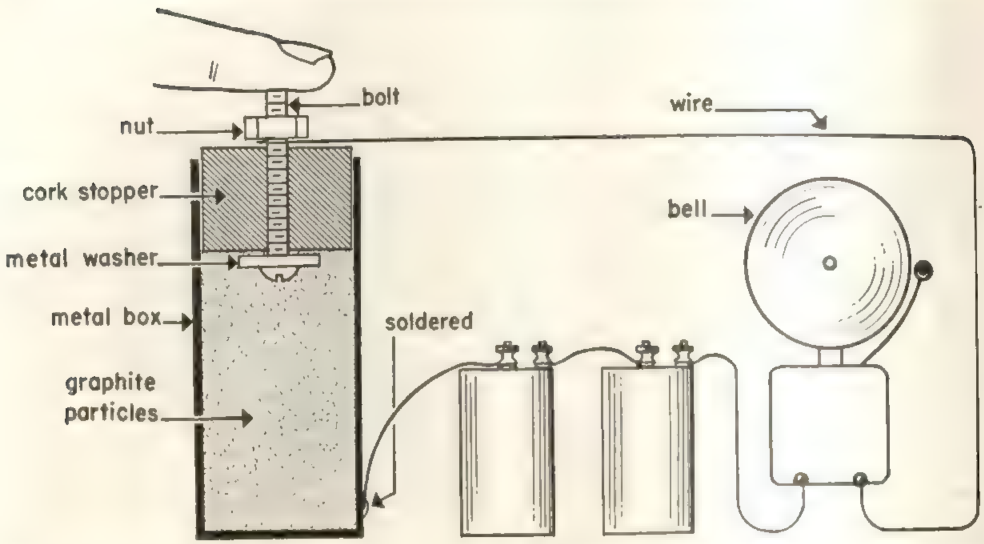
Has the sound of your voice traveled along the wires? No. It has merely been reproduced. Your voice merely modified the electric current. Thus the wires carried what scientists call a *modulated* or modified electric current. It will be much easier for you to understand the importance of this if you perform a simple experiment.

MAKING A CARBON BOX

Obtain a small, round metal box such as a discarded lipstick container. Solder a length of copper wire to it (Fig. 339). Remove the wood from one or more lead pencils and grind up the clay and graphite centers of the pencils. Fill the metal box or tube with this ground-up carbon but leave room for a cork stopper.

The cork stopper needs a little changing, as shown in Fig. 339. Bore a small hole through it with a nail. Bolt a small disk of metal, cut from the cover of a tin can, to the lower end of the cork, and attach a length of copper wire to the other end (Fig. 339). You have made a carbon box or the part of the telephone which modifies (or modulates, as scientists say) the electric current.

Now you are ready to test the sensitivity of your carbon box, your electric current modulator. Connect the wires leading from the box and from the cork to a battery of two dry cells and to something that will show a changing electric current (Fig. 339). You may use a flashlight bulb, a buzzer, a doorbell, an ammeter, or a pair of earphones, whichever is most handy. Suppose you use a bell. As the current



339 *The operating principle of the box of carbon granules in a telephone transmitter may be shown by this homemade current modulator. Why does pressure downward on the movable stopper make the bell ring louder?*

changes, a bell will let you know by ringing loudly or weakly.

As you push the cork into the metal tube, you complete the circuit through the carbon grains. The tighter you squeeze the granules together the better the current will flow, and the louder the bell will sound. The looser the granules, the weaker the bell will sound. You have made a simple instrument which will modulate the electric current.

Here is the basic principle by which the telephone works: Sound waves modulate (modify) an electric current. Carbon particles act as the modulator. The current operates an electromagnet which, in turn, moves a diaphragm. As the diaphragm in the receiver vibrates, it reproduces the original sounds made by the caller.

Communication by telephone, great as its obvious benefits are, has disadvantages. Telephone poles or underground cables for carrying wires are needed. Wires can be torn down by storms. It is troublesome to lay cables under water. Why not do away with wires?

RADIO

In 1872, an American dentist named Mahlon Loomis wrote an article entitled "A Disturbance in the Electrical Equilibrium of the Atmosphere." The article describes an idea on which he obtained a patent that year. A few years later the idea was called wireless telegraphy. Today we call it radio.

PRODUCING WAVES THAT GO THROUGH THE AIR

The reason for giving a little historical background on radio is to show you again how ideas grow as different scientists attack a problem. In 1872, the telephone had not even been invented; yet here was a man who believed that

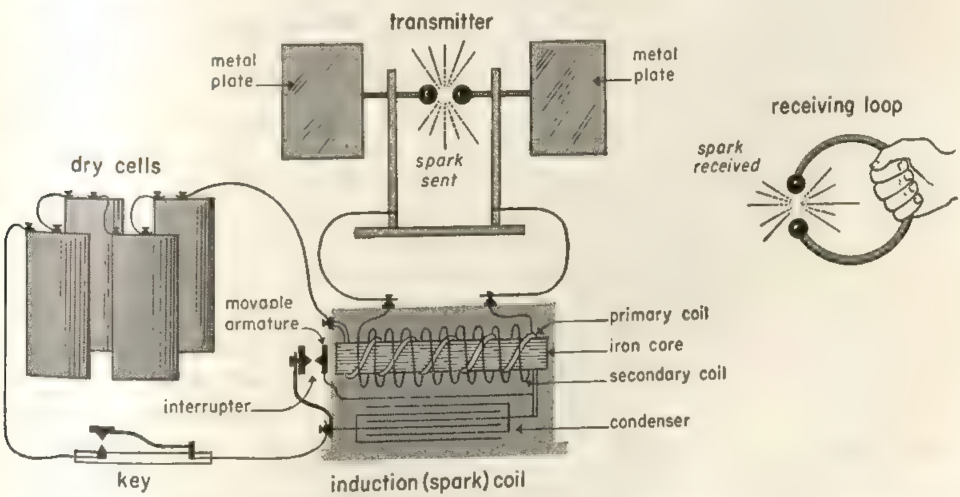
it would some day be possible to send and receive messages by waves sent through the air.

The problem was to find a good way to produce radio waves that could be sent through the air. One of the first scientists to produce or generate such waves was Heinrich Hertz, a German scientist who published his work in 1887. The apparatus he used was so simple that it is not difficult for us to repeat his experiment. In Fig. 340 you see a piece of apparatus very similar to the one Hertz used. With it you can generate radio waves. In 1895 an Italian engineer, Guglielmo Marconi, began to experiment with radio waves as a means of communication. In 1901 he sent the first signal (the letter "s") by radio across the Atlantic Ocean. Soon ships were using Marconi transmitters which used a spark discharge to produce the radio waves (much as Hertz had done).

PRODUCING RADIO WAVES

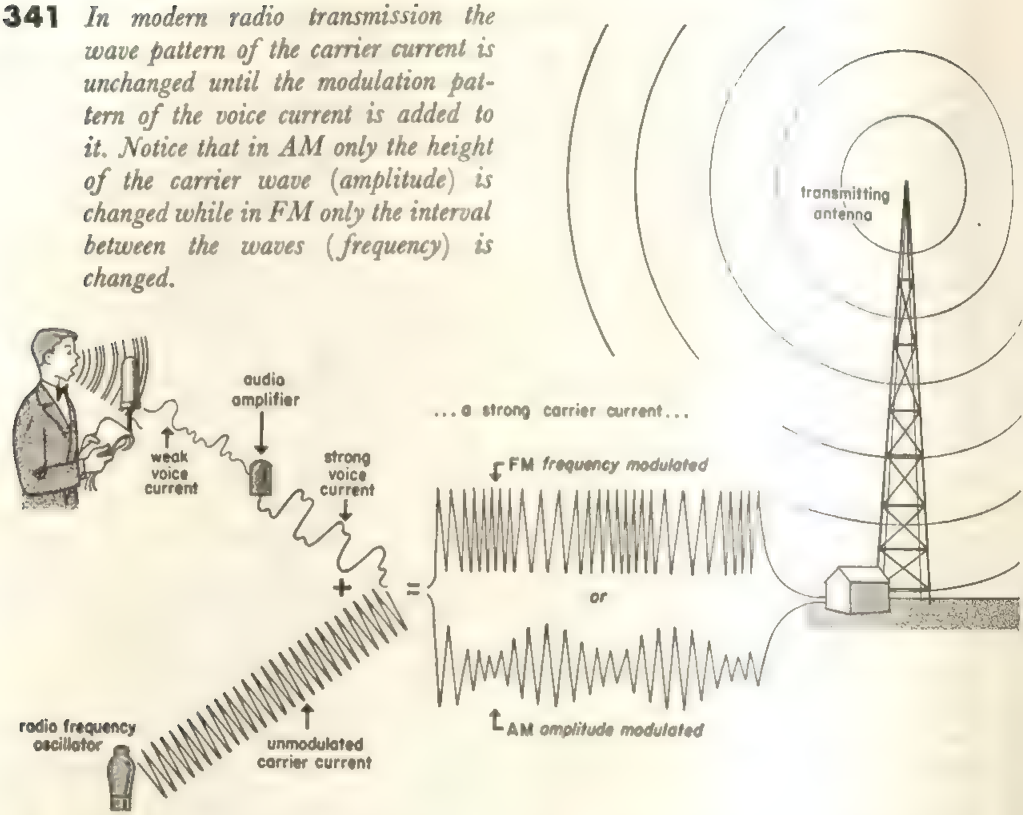
We do not know everything about radio waves and we do not know everything about light. But we know how to produce and use light and also how to produce and use radio waves. Until scientific research reveals to us more about these things we must be content to describe them in terms of their effects. Since radio waves are always associated with electric and magnetic effects we call them electromagnetic waves. They are also called Hertzian waves after their discoverer.

Heinrich Hertz discovered the electromagnetic effect of radio waves when he succeeded in producing some by means of a powerful spark discharge. You may reproduce his results if you too use an induction coil. An induction coil is similar to a step-up transformer. It consists of two separate coils, a primary coil and a secondary coil, wound on a common core of iron. A transformer must be used on alternating or fluctuating direct current. However, an induction coil may be operated on ordinary direct current because it has a built-in interrupter to cause the fluctuations. This interrupter is like the circuit interrupter of an electric bell



340 *A spark transmitter of Hertzian (radio) waves. If the receiving loop is large enough you can receive sparks from the transmitter without any connecting wires.*

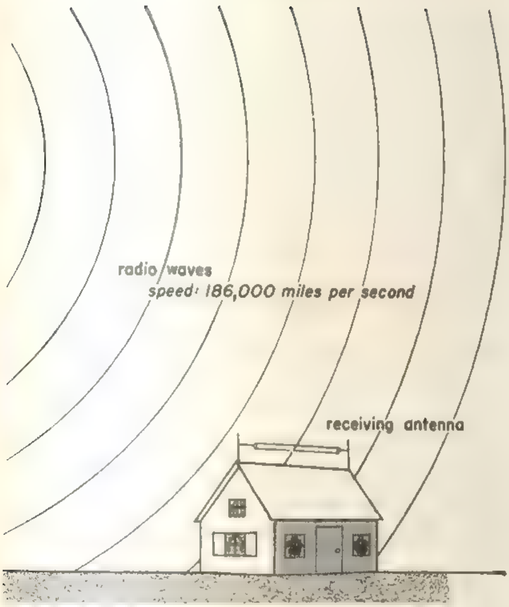
341 *In modern radio transmission the wave pattern of the carrier current is unchanged until the modulation pattern of the voice current is added to it. Notice that in AM only the height of the carrier wave (amplitude) is changed while in FM only the interval between the waves (frequency) is changed.*



or buzzer. Each time the circuit is broken a magnetic field is created by the surge of current through the primary coil. This magnetic field in the primary coil induces an alternating current in the secondary coil. However, since the secondary coil has hundreds of turns more than the primary coil, a great increase in voltage results. This voltage is so great that a spark (like a tiny bolt of lightning) is produced. At that instant, a radio wave is produced. In the early days of radio, spark transmitters were used. Now radio waves are produced by more powerful transmitters.

RADIO WAVES AND WAVE LENGTHS

A radio wave, like other waves, has a beginning, a highest point, a lowest point, and an end point. One wave from beginning to end is called a *cycle*. One thousand radio waves are one kilocycle ("kilo-" means "thousand") and one million waves are a megacycle ("mega-" means "million"). Radio waves are counted by the number of kilocycles or megacycles that a broadcasting station sends out every second. For example, Station KDKA, the Westinghouse station in Pittsburgh and the first radio broadcasting station in America (November 2, 1920), uses a frequency of 1,020 kilocycles (1,020,000 cycles per second). This means that 1,020,000 radio waves leave the station every second. On your radio dial, this station would be tuned in at 1020. Station WNYE is tuned in at 91.5 megacycles. Here 91,500,000 radio waves leave the station every second. Since all these radio waves travel



at the same speed, the speed of light (186,000 miles per second), you can see at a glance that there must be a great difference in their wave lengths.

The wave length is the distance between any point on a wave and the corresponding point on the next wave. All you have to do to find the wave length of any broadcasting station is to divide the distance of 186,000 miles (300,000,000 meters) by the frequency of the broadcasting station expressed in cycles. For example, a station received at 600 on your dial (600 kilocycles) will send out 600,000 waves in one second but there will be a distance of about 300,000,000 meters between the first and the last wave. Dividing 300,000,000 by 600,000 reveals that each wave must be 500 meters long. You remember that a meter is about $3\frac{1}{4}$ feet long. Therefore, this wave would be about 1,625 feet long. Check the frequency and wave lengths of any five stations you can tune in on your radio receiver.

RECEIVING RADIO WAVES

You may have discovered that you are able to tune in many local radio stations and a few stations that are many miles away. Some may be in a foreign country halfway around the earth. Like light waves, radio waves go out in all directions from their source. Within a few hundred miles, the waves near the ground lose their strength but the waves that shoot up into the upper layers of the atmosphere are not all lost. Many are reflected back by a layer of air known as the Kennelly-Heaviside layer in honor of the men who discovered this effect.

Your radio reception will probably be better if your receiver (your radio) has an antenna attached to it. The antenna may be a length of wire strung between poles on the roof, or it may be a loop of wire inside the set, or it may be a metal "fish pole" rod. The antenna receives the radio waves of every broadcasting station within range. The next question is: How do these radio waves carry your favorite programs to you from a studio many miles away? See Fig. 341.

HOW RADIO WAVES CARRY PROGRAMS

Radio stations try to avoid moments of silence for fear of losing listeners. But occasionally between programs these moments occur. If you are tuned into a station at such a time, you will hear a power hum which shows that the station is really on the air. The steady hum is caused by the radio wave which carries the program to you. It is, therefore, called a *carrier* wave (Fig. 341).

If we compare the radio with the telephone, we will see more clearly how the radio operates. In the telephone your voice, acting through the carbon particles in the transmitter, changes

(modulates) the electric current which flows along wires. In radio, the broadcaster's voice changes (or modulates) the carrier wave. In the telephone, a receiver receives the modulated electric current and the current is used to produce sound waves. In radio, a receiver (which you call your radio set) receives the modulated carrier wave and demodulates it; that is, the current is used to produce sound waves.

In the telephone receiver, an electromagnet is acted on by the electric current. The electromagnet then causes a diaphragm to vibrate at sound frequencies you can hear. These vibrations reproduce the sound of the voice. In your radio set, the receiver, a combination of radio tubes and other parts, reproduces the original voices and sound being broadcast by demodulating the radio carrier waves. As you tune them in, the radio waves are changed into an electric current that can operate a loud-speaker. This reproduces sounds as the telephone receiver does.

It is obvious to anyone who has had a glimpse inside a radio that what you have just read is indeed a very brief description of the way a radio works. What of the vacuum tubes and condensers and other apparatus in the radio set? We are leaving a study of these parts to later science courses. If you are interested in making a radio now, the books listed at the end of this chapter will help you.

OUR SHRINKING WORLD

Whether you make a radio or not, you have probably used one long enough to be sure that it is important in your life. It brings the outside world inside your home. Clearly too, the telephone and radio together have given you more time. Because of them you require less time getting news, less time reaching your neighbors, less time ordering food or other household needs. In a few minutes the radio brings an entire nation good or bad news, warnings of storms, news of inventions, and entertaining programs. Whether you go into farming, into business, or into a profession, the telephone and radio will save you much time that you can use for other important things.

In George Washington's day, a journey of 60 miles took an entire day. Today within 1 to 2 minutes you can speak to someone 60 miles away or 600 miles away, and if you wait a little longer you can speak to a person 6,000 miles away. Wire and wireless have made this a small world, indeed. Your neighbor is not a stone's throw away; he is as near as any telephone or radio can bring him.

GOING FURTHER

1 *Making an electromagnet.* Make an open coil type of electromagnet (called a solenoid) by winding 100 turns of #22 wire on a large, discarded wooden spool or section of a cardboard mailing tube. Make similar coils with other sizes of wire—#18, #14, etc. Make some with $\frac{1}{10}$, $\frac{1}{4}$, $\frac{1}{2}$ or 4 times as many turns. Compare the effects when $1\frac{1}{2}$–3 volts of electricity are applied to each of these. Add iron nail cores to the coil. Count the number of nails or paper clips each coil will hold. Use one, two, three, four, or more dry cells in series and test the effect of increased current on the electromagnets.

2 *A two-way telegraph.* Set up a two-way telegraph communication system with some other pupil who has also made the telegraph key and sounder. Fig. 342 shows you how they should be connected. The telegraph key may be made from a straight piece of springy metal, and the sounder from a T-shaped piece cut from a tin box. The electromagnet may be made from

20–30 feet of cotton-covered wire wound around two large iron nails. (Don't stretch the wire across a public thoroughfare.)

3 *Constructing a small radio.*

1. Construct a crystal radio set from parts and plans available at your local radio store. Before electronic tubes were used to detect radio signals, it was discovered that they could be detected by using a crystal of galena.

2. Construct a one-tube battery-operated radio set from parts and plans you can obtain at your local radio store. Compare the results with the crystal set.

4 *Radio as a Hobby*

If you want to learn more about radio and want to build a radio, perhaps you should begin by reading the following books. As you read, you may want to do the activities described below.

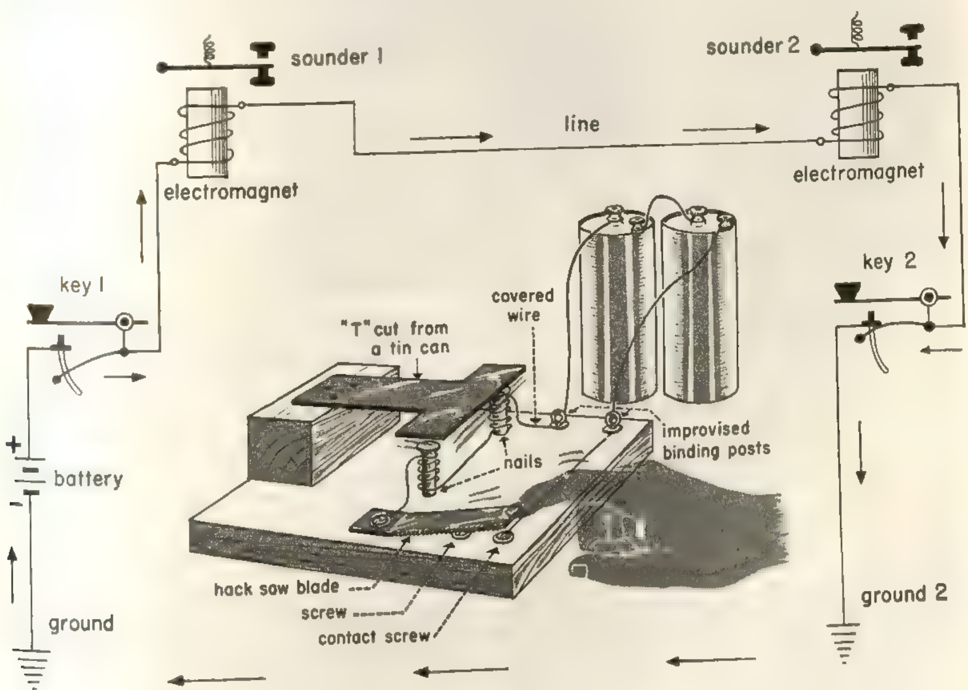
Elements of Radio by William Marcus and Ralph E. Horton, Prentice-Hall. This book is easily the most clearly written text on radio for the beginner who is prepared to delve deep into the subject.

The A.B.C.'s of Radio prepared by the Electronics Department of the General Electric Company, Schenectady, N.Y. If you understand all this brochure contains, you will be well on your way toward being a radio repairman.

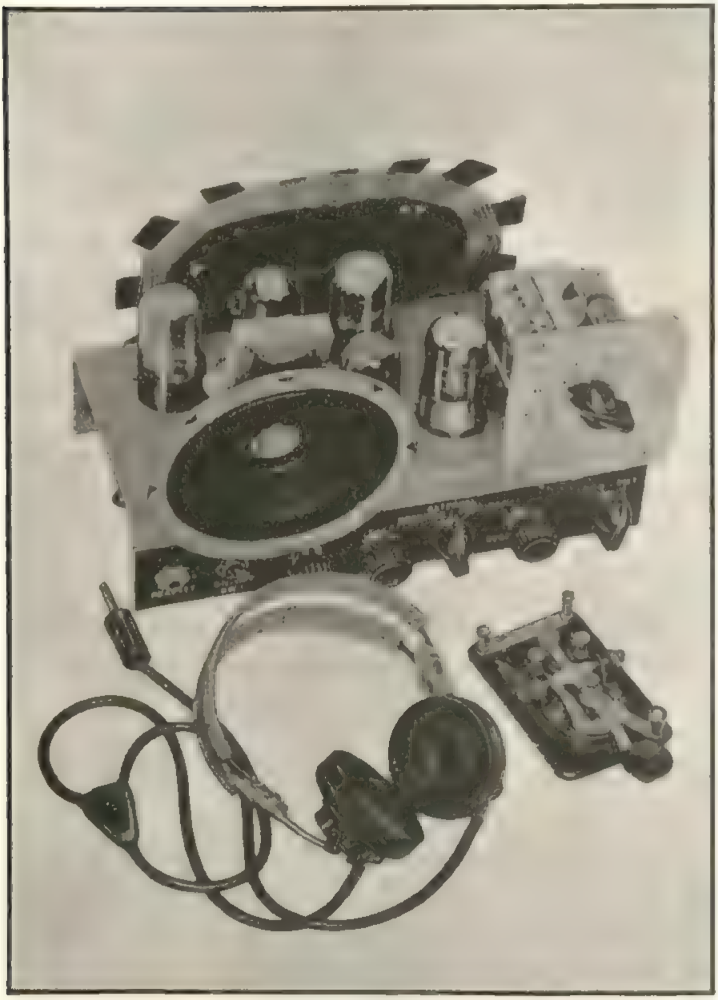
R.C.A. Receiving Tube Manual. You will need this book for the data it contains on all types of electronic radio tubes.

The Radio Amateur's Handbook and *A Course in Radio Fundamentals* published by the American Radio Relay League, West Hartford, Connecticut.

1. Build a five-tube superheterodyne receiver. You can obtain the kit containing all the necessary parts and complete directions including step-by-step pictographs which show you just how to assemble every part of the set. This and the other sets below may be obtained from the Eagle Electronics Corp., New York City.



342 *A homemade telegraph key and sounder in the center. Using this set to receive code signals from a similar set, you will have to connect them as shown in the wiring diagram. You will have to hold your key down to listen.*



343

This radio set, which you can make easily from the Q–5 Pictograph Kit, will serve the purposes of four instruments. With a microphone or electric phonograph pickup you can "broadcast" your own radio program within a radius of 30 feet or make a public address (P.A.) system. (Eagle Electronics Corp.)

2. Build a phono-oscillator. This is really a tiny transmitter which you may operate without a license provided you do not attach an outdoor antenna. By connecting it to the wires from a phonograph pickup (crystal type used on electric phonographs) you can "broadcast" recorded music and listen to it as it is received by a radio set within 30 feet. With a slight modification (the addition of a microphone to set 2) sets 1 and 2 become a P.A. (public address) system.

3. Build a code practice oscillator with which you can simulate the effects of a genuine transmitter. By practicing with this oscillator, you can prepare yourself for the test you must take if you want to become a licensed amateur radio operator.

4. If you prefer, you may obtain a kit, the Q–5, which combines a receiver, a phono-oscillator, a code practice oscillator, and an amplifier, all in one. It is illustrated in Fig. 343.

5 *Words are ideas.* Can you use these words in a sentence which will give their meaning? Use the glossary.

antenna	Morse code
armature	oscillator
carrier wave	receiver
current	relay
wireless telegraphy	sounder
frequency	transmitter
key	electromagnet

6 *Put on your thinking cap.*

1. What is the simplest kind of apparatus you must have in order to send information by electricity?

2. Compare the advantages and disadvantages of communicating by telephone and by radio.

3. Why is it necessary for the Federal Communications Commission to regulate and license those who wish to broadcast?

7 *Test yourself.* In your notebook, complete the following sentences with a correct word or phrase. Do not mark this book.

1. The first electric telegraphs required ...... wires.

2. At the end of these wires were ....

3. Later, ... were placed at the end of the wires.

4. The man to whom Morse was most indebted for helpful ideas which he used in making his telegraph was ....

5. The special type of switch Morse invented for sending telegraph messages is called a ....

6. Morse designed his telegraph receiver so that an ...... caused a ...... to move back and forth.

7. Morse discovered he could send telegraph messages much longer distances if he used ....

8. The two operating parts of a telephone receiver are an ...... and an .... The flow of current in a telephone receiver is modulated by means of a device containing grains of ....

9. Later, Marconi discovered how to transmit radio waves across the Atlantic Ocean by means of a ...... oscillator.

10. When a radio transmitter sends out radio waves that oscillate 1,020,000 times a second, the transmitter is said to broadcast at ...... kilocycles.

8 *Adding to your library.*

Get the small free pamphlet *Eyes and Ears for the Millions*, Westinghouse Manufacturing Co., Pittsburgh 30, Pa.

CHAPTER 28

REPRODUCING WHAT WE SEE AND HEAR

Governor Leland Stanford of California was willing and able to spend $40,000 to win a $25,000 wager. You'll probably agree that it was money well spent because it paid for the production of the first moving picture. The story is as unusual as the wager.

Governor Stanford believed that at times a horse lifts all four feet off the ground while it is galloping. Others were equally certain that a horse does not do this. Neither side had proof, because the feet of a galloping horse move too quickly for the human eye

to follow. Of course a movie would provide the evidence, but in 1872 no motion picture cameras were available. So Stanford hired the English photographer Edward Muybridge to obtain the necessary evidence.

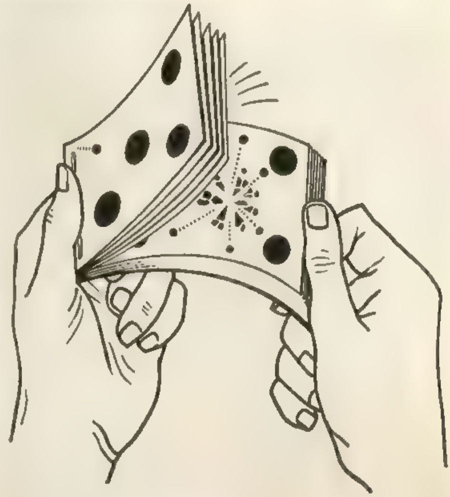
Muybridge decided to let the horse solve the problem. He set up 24 ordinary cameras in a row and he attached long, thin strings to their shutters. The strings were arranged so that as the horse galloped through them the cameras snapped and caused 24 pictures to be taken in rapid succession. Several of the pictures showed all four of the horse's feet raised from the ground (Fig. 344) and Stanford won his bet. But you have heard only half the story.

All 24 pictures were mounted in a revolving frame similar to a toy children still enjoy. When the frame was spun—presto, the horse actually appeared to be galloping. It was the first time anyone had ever seen a moving picture of a living animal in action.

BEGINNING OF THE MOVIES

For the next ten years, Muybridge used the same arrangement of cameras to take photographs of people and animals in motion. But in other parts of America and Europe, inventors began to devise better ways to take pictures of moving objects and better ways to view the pictures. One early method is still employed in the penny-arcade movie machines which you operate by turning a handle. In these machines,

344 *The first motion picture. In which pictures are the actions duplicated? (American Museum of Natural History)*



345 *A homemade flip booklet showing the splitting of an atom of uranium and the beginning of a chain reaction. Many other processes described in this text may be illustrated by flip booklets. How does this illustrate the principle used in making animated cartoons?*

a series of post-card-sized photographs is flipped past the viewing window to produce the illusion of action. You can create a similar effect by flipping the pages of a flip book (Fig. 345).

The perfection of photographic film in 1884 by George Eastman marked the real beginning of the modern motion picture. Within five years, Thomas Edison and an associate of his, W. K. L. Dickson, had invented a machine for viewing motion pictures printed on transparent film. An electric light shining through the film provided the illumination, but only one person at a time could see the picture. Edison also invented a camera with a rotating shutter for taking the pictures on film.

REPRODUCING IMAGES AND SOUND ON FILM

By 1894, Edison had a profitable "movie show" in operation in a store on Broadway in New York City. Soon other parlors were opened but they gave way to moving pictures or "movies" which were "added attractions" in vaudeville theaters. The first films were "shorts" with a running time of one or two minutes. Not until 1903 was the first "story picture" produced. It was the famous "The Great Train Robbery." In 1927, audiences witnessed the first sound film or "talkie," "The Jazz Singer," featuring Al Jolson. The sound for this film was recorded on phonograph records played while the picture was shown. Within a short time, a method of recording sounds on the film with the moving picture was substituted for the disk recordings. The motion pictures you see in theaters today are all of this later type.

Of course motion pictures are entertaining and educational, but they are also historical records. You may want to make such records preserving the personal history of your family and friends or of places you visit. You should, therefore, know a bit about photography and how movies are made.

LET'S MAKE A PICTURE

We are going to start with the simplest kind of picture—a shadow picture. Draw the dark shades and put out the lights in the room. Now, even if it is daytime outside, it is dark enough in your room to expose a piece of #4 or #5 photographic contact paper

for a moment or two without spoiling it. Contact paper is a type of paper used to print photographs. You can get a box of it in a store which sells photographic supplies. Examine the paper. You will find that one side of the paper is dull. The other is smooth and glazed because it is coated with certain chemicals. These chemicals undergo changes when exposed to light.

Place the paper on a table top with the smooth, coated side up. Lay two or three keys on top of the paper. Now make sure that the rest of the paper in the box is well covered. Turn on the room lights for a minute or two. When you develop the paper according to the directions given in "Photography as a Hobby" (p. 510), you will discover that the paper bears a white shadow picture or image of the keys.

The film you place in your camera is coated with similar substances that are sensitive to light. When you click the shutter on the camera, you allow light reflected from the subject you are photographing to enter the camera and strike the coated side of the film. As no other light can enter the camera, the effect produced will be an image of the subject on the film in black, white, and various shades of gray. But the image will not become visible until the negative has been developed as described on page 513.

NEGATIVES AND POSITIVES

Let us suppose you are taking the picture of a little girl (Fig. 346). As dark colors reflect little light, the tree behind her will send few light rays into the camera. Her light skin and the balloons she is holding will reflect many rays into the camera. Thus the film will be affected very little by the tree, and affected a great deal by the reflections from her skin and dress, the balloons, and the white fence. In the negative the girl's face will be almost black. Shadows will be indicated by various shades of gray. A picture of this kind is shown on the left in Fig. 346. It is called a *negative* because it is the exact opposite of the picture you want—the print, called a *positive*.

From the negative, it is possible to produce positive prints. These positives are really shadow pictures like the one you made with the keys. The negative is placed on a type of contact paper and light is passed through the negative. As you can see, the light passes easily through the light portions of the negative (the tree) but the dense, dark portions (the fence) allow but little light to strike the chemicals on the printing paper (Fig. 346 right).

You can make both positives and negatives on film, on paper, or on glass provided they are coated with the proper chemicals, exposed in the proper way, and correctly developed.

We are not going to describe the nature of these chemicals, the kinds of film, methods of exposing the film, or the complete use of a camera at this point. But because we believe that every one of you will want to become fairly expert in photography we have devoted a section, "Photography as a Hobby" (p. 510), to this important method of keeping records. We know you will want to use photography as a means of keeping a record of your life. If you are not already an expert photographer, read this section as soon as you can.

RECORDS ON GLASS AND FILM

You are probably familiar with a type of record kept on glass which is used by your teacher. This is the glass lantern slide which can record pictures as well as words. The projector for

showing these slides is called a lantern slide projector or stereopticon.

Lantern slides are really photographs printed on pieces of glass or film instead of on paper. Ask your teacher to let you examine some lantern slides of various sizes. Hold one to the light. Notice that you can look right through the light parts.

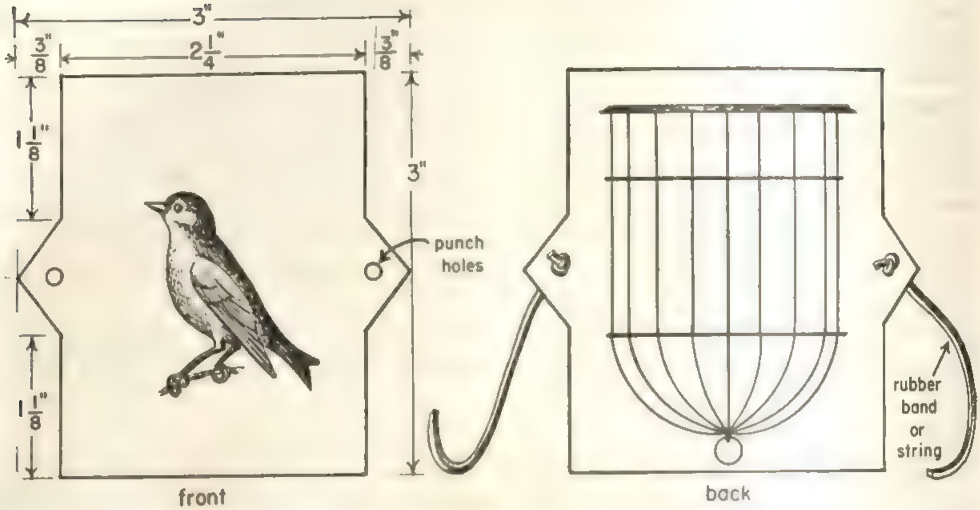
When people think of photographic film, most of them think of the film that they use in their cameras for taking snapshots. Photographs are usually printed on paper from the developed film. It may not have occurred to you that photographs can be printed from the film onto a piece of lantern slide glass or onto another film. Yet this is the way lantern slides, transparencies, and motion pictures are made. The transparency of the film makes projection on the screen possible.

PERSISTENCE OF VISION

The effect of motion as you see it in the movies is an illusion. By an illusion, we mean a trick played upon us by our eyes. The actors are not moving either on the film or on the screen. The images of the actors are moving and the film is moving rapidly. The effect is created because we see two different images within so short a period of time that we cannot forget the first picture before we look at the second. This makes the two pictures appear to blend. The blending of pictures occurs when we see one picture after another in less than $\frac{1}{16}$ of a second. The blending is due to what is called *persistence of vision.*

By means of the simple device shown in Fig. 347, you can test your own persistence of vision. If you whirl the card rapidly enough, the bird will appear to enter the cage.

346 *The picture on the left is a negative. The one on the right is a positive. Compare the light and dark portions of each.*



347 *When you make this device be certain that you draw the cage and bird as shown (the cage is drawn upside down on the back of the card). To operate, twist the rubber bands so that the card twirls when it is released. What causes the optical illusion when the card is in motion?*

Can you explain the reason why the bird appears in the cage even though on the card it is actually on the other side of the cage? When we twirl the card, we see the bird for less than $\frac{1}{16}$ of a second. But before the $\frac{1}{16}$ of a second is gone we have twirled the cage, on the opposite side of the card, before our eyes. Since the image of the bird persists or lingers in our eye, we see it and the cage together. Thus we see the bird in the cage. This simple effect is at the heart of the motion picture.

Think of a motion picture camera taking pictures of a runner. The pictures it takes are like those you take with an ordinary camera except for one thing. It takes one picture after another and they are taken in about $\frac{1}{30}$ of a second. Later when the pictures of the runner are projected on the screen, each picture is permitted to remain on the screen less than $\frac{1}{16}$ of a second. Thus it persists or lingers long enough in your eye so that the next picture blends with it. Thus the runner appears to run.

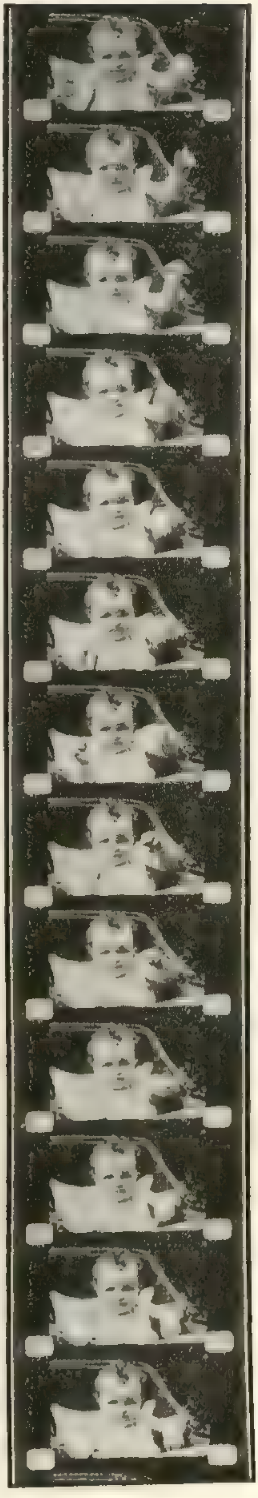
Look at the strip of film in Fig. 348. If each picture were flashed rapidly before your eyes it would appear as if the figure on the film were in motion. Actually, each is a still. Normally, the motion picture projector will flash these pictures at a speed of 16 per second or faster. You know what happens if the projector slows up. You see a flickering; the motion is no longer smooth because each picture is being shown on the screen more than $\frac{1}{16}$ of a second after the one preceding it. Persistence of vision enables us to see apparent lifelike movement when a motion picture is properly projected.

MAKING MOVIES TALK

But men were not satisfied with motion only. They wanted their actors to talk as well. They wanted to hear the noises of living things and their surroundings. How did men get photographs on film to talk?

Examine a piece of film with a sound track. What you see is really a photograph of sound. How is a sound track placed on the film?

In 1887, Heinrich Hertz discovered that certain metals give off electrons when struck by light. This fact became the basis for the invention of the electric eye or *photoelectric cell*. A photoelectric cell changes light into a flow of electricity. This electricity may be used to do many things. For instance, it may be used to operate a switch which opens a door. Have you ever walked up to a door in a department store only to find that it opened before you touched the knob? A photoelectric cell containing the metal selenium helped to open the door. As you walked to the door, you interrupted a beam of light which was focused on a photoelectric cell. This interrupted the flow of a small amount of electricity from the cell which was connected to a special switch. This, in turn, operated an electric motor which opened the door. Thus light energy was turned into electrical energy. But how does a photoelectric cell make sound pictures possible?



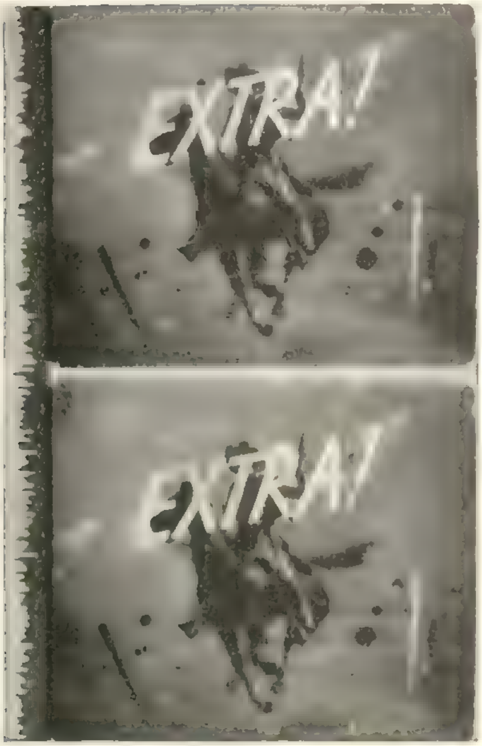
348

A strip of 16 mm. silent motion picture film (enlarged). Although printed on film, these are positive pictures. Look at the child's hands. Why would the viewing of these pictures in rapid succession produce an illusion of motion?

THE SOUND TRACK TALKS

When an actor stands before a microphone, his voice, as you know, sends forth sound waves. These sound waves cause a specially rigged mirror to vibrate. In turn the vibrating mirror reflects a beam of light. The movement or strength of the light beam depends on the sound waves which produce it. The light beam in its turn is focused on the edge of the film which becomes the sound track.

Just as light changes the chemicals and makes marks on ordinary film and photographs, so this beam of light makes a mark on the sound track. If you examine a picture of the sound track (Fig. 349), you will see this line.



349 *Two frames of a 35 mm. motion picture film (enlarged). Note the irregular pattern to the left of the pictures. This is the sound track.*

Now when the film is run through the projector, a beam of light from a small lamp is focused on these marks, the sound track. This light, which is affected by the heavy and light portions of the sound track, goes on to reach a photoelectric cell. This cell changes the flickering beam of light into a current of electricity. As in the radio or telephone, electricity is turned into sound waves.

In short, sound waves can be made to control the light waves produced. The light forms a line, or sound track, on the film. This line breaks up a light beam which is focused on it. When this light beam hits a photoelectric cell, the light beam is changed into an electric current. The current is weak and it is made stronger with the help of an amplifier employing vacuum tubes like those in radio receivers. Finally, the electric current is turned into sound by the loud-speaker.

SOUND RECORDINGS

The equipment used to show a sound film is called a sound projector. It is never described as a talking machine. Yet it might well be so described for it reproduces voices, music, and other sounds far better than did the first talking machine invented by Thomas Edison in 1877. For years the only talking machines were phonographs or gramophones. Now there are many types of sound recorders and reproducers.

TALKING MACHINES—THEN AND NOW

Edison's first talking machine had few parts. It was just a metal cylinder with a means of rotating it; it had a short, cone-shaped speaking tube and a blunt needle attached to a thin diaphragm at the narrow end of the tube (Fig. 350). Edison shouted into the speaking tube while the cylinder, covered with a sheet of tin foil, was rotated by hand at a uniform speed. The sound waves moved the diaphragm in the speaking tube. The diaphragm in turn moved the needle so that it pressed little grooves into the tin foil. To play the recording, Edison returned the needle to its starting point on the cylinder and again turned the handle. The sounds that came out of the tube could be recognized as the words he had spoken into it.

To those who had never before heard the human voice reproduced by a machine, Edison's invention was an astounding device. Actually, the sounds

coming from the speaking tube sounded terrible. One or two playbacks were all you could expect before the foil had to be discarded. Of course, Edison realized these defects and contributed many improvements. During the 70 years that followed his original invention, the following improvements were made in phonographs:

1. Wax, glass, paper, and plastic materials, as well as magnetic wire or tape, replaced the tin foil.

2. Except on office dictaphones (used for the temporary recording of messages to be copied by a typist) cylinders were replaced by disks.

3. Mass production of records is made possible by preparing the master copy on a metal disk. From this original or master record thousands of duplicates can be made. The original (the master copy on metal) is placed on the blank duplicate. Heat and pressure are used to transfer the grooves to the duplicate much as you would use heat and pressure to impress a seal in sealing wax.

4. On the machine, the record is turned by electric motor, not by hand. This insures uniform speed and it is also more convenient. Speeds of 78, $33\frac{1}{3}$, and 45 r.p.m. are now in use ("r.p.m." means "revolutions per minute").

5. The shape of the horn was improved and horns were later replaced by electrically operated loud-speakers found on every modern phonograph.

6. The quality and design of phonograph needles has been improved to reduce wear and tear on the record and undesirable surface noise as well.

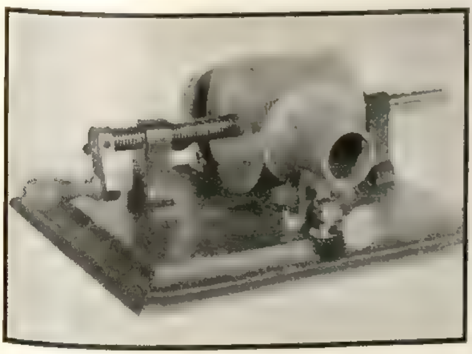
7. The "hill and valley" type of needle groove has been replaced by grooves that have a wavy appearance but are of the same depth. This saves wear and improves the quality of the reproduction.

8. Crystals that produce tiny electric currents when they vibrate are now used in the pick-up arms of playback instruments. This makes it possible to regulate the tone and volume of the sound by means of radio tubes as in a radio receiver.

9. Long-playing records and automatic record changers have added to the pleasure of listening to recorded music.

All these improvements have contributed a great deal to the popularity and enjoyment of recordings. New uses

350 *Edison's first phonograph* (left) *and a replica that actually works* (right). *First you have to shout into it and then when the record is played back you have to listen closely to hear anything.* (Left, *Thomas A. Edison Foundation*, right, *General Motors*)



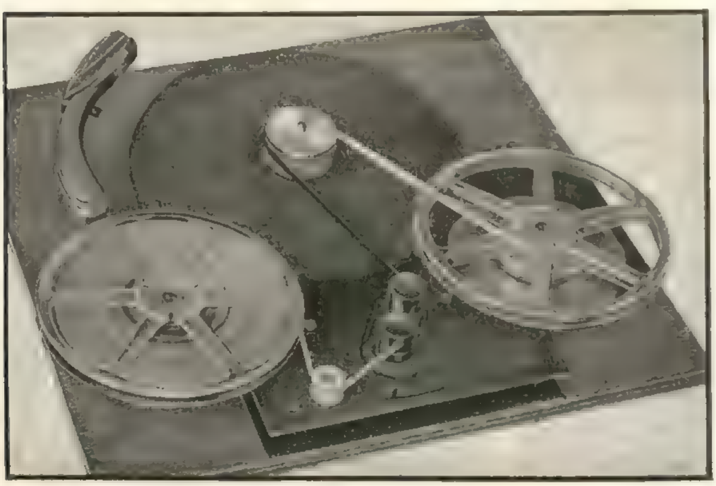
have also been found for them. Radio stations maintain libraries of recorded music and sound effects. They also make recordings, called transcriptions, of entire programs. Transcriptions may be used for rebroadcasts or in court to prove that a particular statement was or was not made. Many families have voice recordings of their relatives and friends. Inventors are still at work seeking new and better ways to preserve and to reproduce sounds of all kinds.

RECORDING SOUND ON WIRE AND TAPE

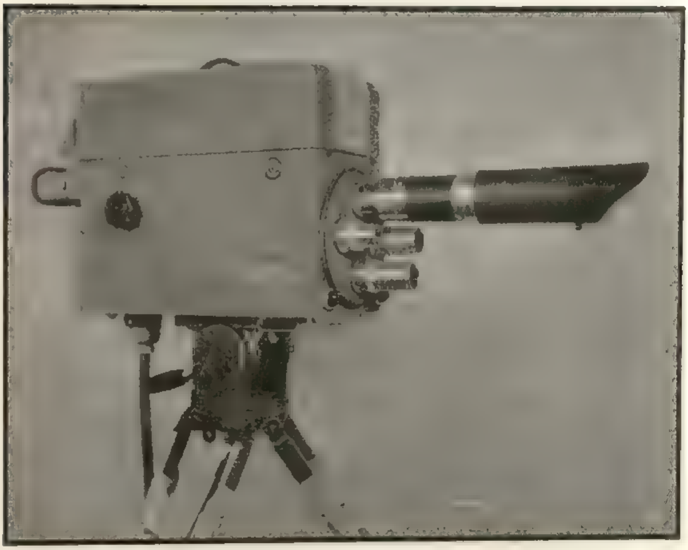
One of the new ways of recording sound you have already learned: The pattern of sound waves is photographed on the edge of a piece of motion picture film. Other recently developed methods record sounds on wire or on metal-coated paper tape. These new machines have the advantage of combining recorder and reproducer in one small case easily carried in one hand. Transcriptions on wire or tape can be run continuously for more than an hour without interruption; they do not require needles; they do not wear out; and the record can be erased so that the wire or tape can be used over and over again.

The principle of operation of wire and tape recorders is simple. It is based on two facts: (1) electricity can produce magnetism; (2) magnetism, in its turn, can produce electricity. To make a recording, you fasten an empty spool or reel the size of a saucer on one side of the device and a full spool on the other side (Fig. 351). The wire or tape is threaded through a "head" containing electromagnets. Then a motor is turned on and you speak into a microphone. The vibrations of your voice cause varying electric currents as in the telephone. The tiny current is increased by radio tubes and fed through the coils in the recording head. Thus a pattern of magnetism is impressed upon the wire or tape. The molecules of the metal arrange themselves very much the same as iron filings do when you sprinkle them on a piece of cardboard placed over a magnet.

During the playback, the process is reversed. The magnetic pattern causes an electric current to be produced in the coils. This current is amplified, fed through a loud-speaker, and the sound reproduced. However, the magnetic pattern in the wire is not disturbed.



351
A magnetic tape recorder. This kind of recorder can be used over and over again hundreds of times. What is the purpose of the large turntable? (*Tapetone Manufacturing Co.*)



352
A television camera. This one may be used in places where there is not enough light for ordinary equipment. (Radio Corporation of America)

The same recording may be played over and over again with no apparent loss of quality. Nevertheless, it is the opinion of some experts that the best wire recordings are not yet as good as the best disk records. Before investing in either kind you should hear them both and compare their advantages and disadvantages.

REPRODUCING VISUAL IMAGES BY TELEVISION

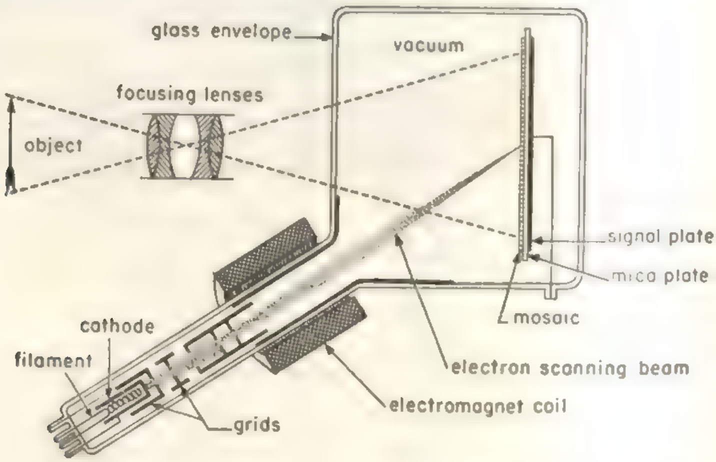
The inevitable result of research and improvements in recording what we see and hear by means of phonographs, photographs, movies, radio, and the like, was a demand for radio vision. Television is the answer. It does not preserve images or make a record but it provides a means of communication that is vivid and exciting. It combines several ideas you have encountered before in the explanation of moving pictures, sound film, radio, and photography. These are the effect of light, the persistence of vision, the energy transformation in a photoelectric cell, and the modulation of radio waves. Let us see how these principles are used to broadcast light waves and images.

BROADCASTING IMAGES

To begin, we shall visit the television box at a ball game and peep into the television camera for a moment before the game starts. There we see the lenses you might expect to find in any camera but also there is a peculiar radio tube that looks like a pot made almost entirely of glass (Fig. 353). Light coming through the lenses is focused upon a screen in this odd-looking radio tube. The tube is called an iconoscope (ī kŏn′ō skōp) and the screen is called a mosaic (mō zā′ĭk) because it has an inlaid design.

The mosaic is only a few square inches in area, yet it contains nearly 200,000 individual photoelectric cells, each insulated from its neighbors. A mica plate serves to insulate the mosaic from a metal backing called the signal plate. Every time light waves strike one of the tiny photoelectric cells a number of electrons are released from it. The

353 *An iconoscope is the seeing eye of standard television cameras. The flat plate in the bottom of the "pot" is the mosaic screen.* (*Radio Corporation of America*)



electrons flow away through the ground wire from each of these tiny photoelectric cells in proportion to the amount of light reflected from the subject being televised. Since electrons are negative charges, this removal of electrons leaves some positive charges stored in most of the tiny cells. To balance or neutralize these positive charges a new, controlled stream of electrons is now shot at the mosaic. This stream of electrons is controlled so accurately by an electromagnet and several grids that it moves across, or scans, 525 rows of mosaic cells 30 times a second. This rapid scanning is needed to avoid flicker. But it means that over eight million (525 × 525 × 30) electrical impulses are transmitted every second! As the electron beam strikes each cell spot on the mosaic, it sets free an orderly succession of electric impulses equal to the stored charges. Although the succession of electric impulses is orderly, the impulses themselves vary in strength. These variations in voltage are then amplified and used to modulate a very high frequency carrier wave. Television is very much like ordinary radio in that a modulated carrier wave is sent out by the transmitter and demodulated by the receiver.

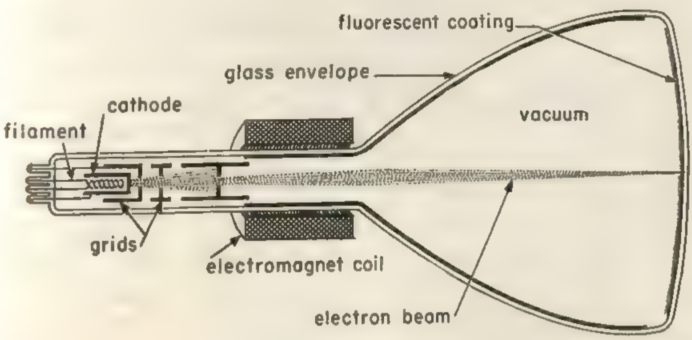
REPRODUCING THE IMAGE ON THE RECEIVER

The job of the receiver is to change this flow of electrons back into a visual image. Many vacuum tubes and other electric equipment as well as much complicated wiring are needed to turn the trick. Only the technical expert

who builds or repairs television receivers needs to be concerned about these details. But one part of the receiver interests everyone. This is the kinescope. The television kinescope is a long tube with a broad, slightly curved front surface on which the image appears (Fig. 354). Television tubes are also known as cathode-ray tubes. Their long necks contain pieces of filament-heated metal (called *cathodes*) from which a stream of electrons is shot out. This electron stream is controlled by several grids and is deflected by an electromagnetic coil so that in the kinescope tube it scans (moves across) the surface at the broad end of the tube (Fig. 354). This scanning is timed to match the scanning of the electron beam in the iconoscope tube.

By now you have probably seen a television receiver and the screen. The screen is really the broad surface of the kinescope tube. It is coated on the inside with a white or greenish-white substance.

There is little difference between this substance and the material used to coat the inside of the ordinary fluorescent light tube. When either material is struck by charged particles such as electrons, it glows for an instant in proportion to the intensity of the current produced. The image you see is caused by the momentary glow of the coating material on the broad surface of the kinescope when it is scanned by the electron beam. The scanning is so fast that our eyes are deceived into seeing a continuous image, just as we see a continuous line of light when we watch someone swinging a lantern rapidly in the dark. This is due to persistence of vision. Television, like motion pictures, depends on familiar scientific principles.



354 *A kinescope is the picture tube in a television receiver. Its fluorescent coating (the screen of a television set) glows for an instant as the electron beam strikes it. These tubes are protected by a piece of glass when they are mounted in your receiving set. (Radio Corporation of America)*

TELEVISION'S COUSINS

You know now that radio and television depend on the transmission of waves. But not all waves have the same wave length or frequency. Radio and television are closely related in their wave lengths, as you can see from Fig. 355. If you look farther toward the bottom of the diagram of wave lengths in Fig. 355, you will see its bands resemble the bands of colors in the spectrum we see in the rainbow.

Each wave length has its own particular uses. At one end of the radio spectrum (Fig. 355) are the very long waves that are used in ordinary radio broadcasting. Next there are the shorter wave lengths used by the police, by amateur radio broadcasters (the hams), by ships, by airplanes, by foreign stations, and by the Coast Guard. Then come the very short waves, called *ultra-short* waves, used for television. Finally, there are are extremely small wave lengths, called *microwaves*. These microwaves are being used for walkie-talkie two-way communication, for long-distance telephone calls between several Eastern cities, for television relays, and for television's cousins — radar and G.C.A. (ground control of approach) for aircraft.

RADAR

Radar is a cousin to television because its receiver uses a cathode-ray tube with a screen on which an image appears. Radar is also a cousin to an echo and to a reflected light. RA–D–A–R is an abbreviation for Radio Detection and Ranging.

Detection means the act of discovering the presence of something. Have you ever detected something you could not see, such as the sound of an airplane flying through a solid bank of clouds? You knew it was there but you did not know its speed, its direction of flight, or its distance from you. Radar reveals all these things about any fair-sized object in the path of its microwaves. The radar instrument sends out waves which can be focused and directed almost as you can focus and direct the beam of a flashlight on an object.

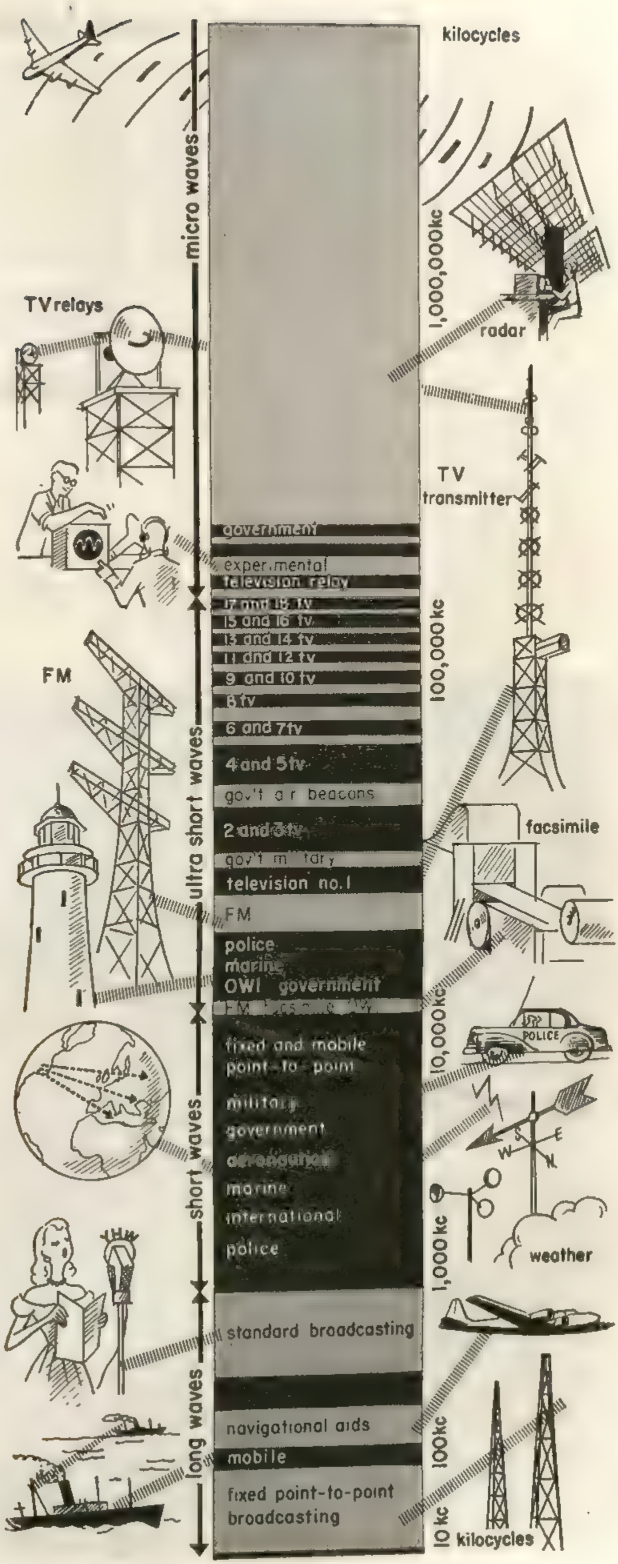
Radar waves are sent out in short bursts rather than in one continuous beam. If there is an echo, it is received on the radar screen between these bursts of broadcast radar waves. If the radar waves strike an object such as an airplane or a ship or the shore line, they bounce back toward the radar instrument. Here they are received and indicated on the screen of the cathode-ray tube as spots or dots of light. The returning radar wave is like an echo. The idea is quite similar to the old trick of tooting the foghorn. By listening for and timing the echo, experienced river pilots are able to estimate their distance from the shore. Now all they need do is keep an eye on the screen of their radar receiver. It is marked off with circles to show the range or distance. The size and shape of the pips on a radar screen reveal to the trained observer the kind of object his microwaves are echoing from. Outlines of land areas are so clear that their pattern on the radar screen resembles a map (Fig. 356).

GROUND CONTROL OF APPROACH

Radar can be used for many jobs. It is useful in military operations for locating targets and for giving warning of attacks. In peacetime, radar is used to warn ships of their approach to other ships or to land. It is used to locate storms, and to control airplanes coming in for a landing in bad weather. The system of ground control of ap-

355

The radio spectrum resembles the sun's spectrum. Both are divided into bands of different frequencies and wave lengths. Which are the longest and which are the shortest radio waves?



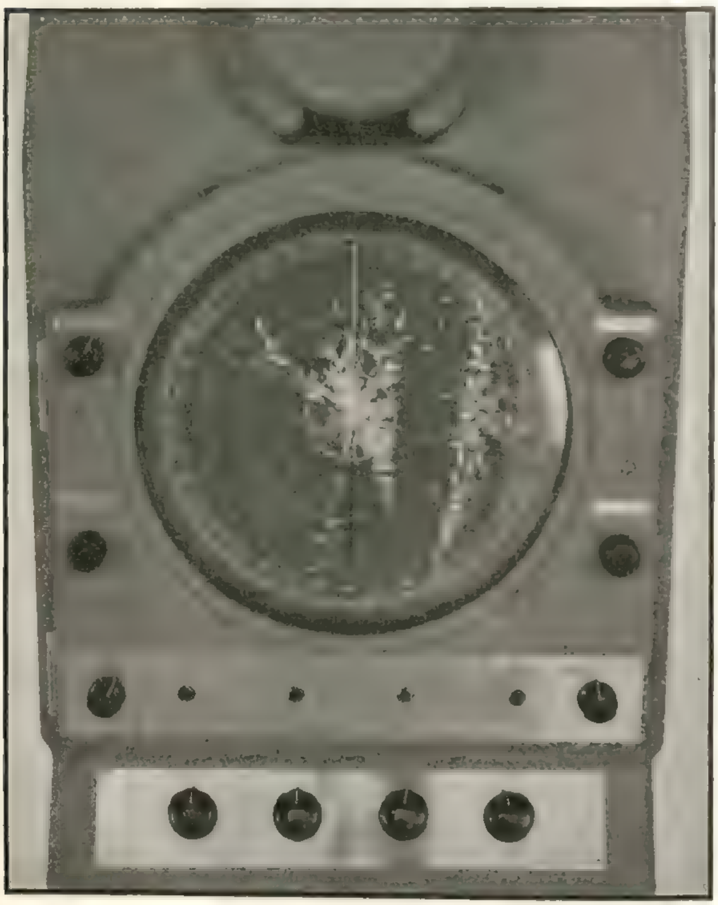
proach, or G.C.A., has saved many planes that otherwise would have crashed because the pilot could not see the landing strip through the fog. G.C.A. involves tracking the plane by radar, reporting its position to the pilot, and then "talking him down" by radio to the landing strip.

THE LAST WORD

Radar is, as this book goes to press, the last word in communication. With it, scientists have sent microwave signals to the moon and have caught the returning echo. Where do we go from here? Some say newspapers will be printed in our own homes by radio. Machines which do this have been demonstrated successfully. Others point to the tiny radio receivers already in existence. They predict that everyone will be able to carry his own radio receiver in his pocket or on his wrist. Two-way radio-telephone service to automobiles and to ships is now in use. Research will doubtless bring new developments in communication.

GOING FURTHER

1 *Using an electric eye.* If your teacher has a photoelectric cell and the necessary amplifier and relay, or if you can obtain this elsewhere, set up the apparatus so that it will automatically count the pupils as they enter your classroom. Think up other uses for this apparatus and test them.



356
Radarscope showing the screen and the control panel. The spots of light on the screen are produced by radar waves that have been reflected back to this receiver by some distant object. The circles and scale help the operator to determine the distance, which is called the range. (Radio Corporation of America)

2 *Persistence of vision.* You can also draw a picture of a television screen on one side of a card 2 inches × 3 inches and a picture of a person on the other side of the card. Space it so that when you attach the card to a dowel stick and twirl it, the person will appear to be on the screen.

3 *Making a flip book.* Make a movie booklet of one or more processes involving motion such as the take-off or landing of an airplane. This is done by first cutting out 30 or 40 pieces of blank paper 1 inch × 2 inches. On each draw a picture of the same object but in a slightly more advanced stage of the motion. Fasten the entire set of drawings together at one edge as shown in Fig. 388 and then holding the booklet in the left hand, run a finger of the other hand across the open edge of the booklet. You'll see a movie.

4 *Words are ideas.* Can you use these words in a sentence which will give their meaning? Use the glossary.

kinescope	persistence of vision
film slide	time capsule
film strip	microwaves
iconoscope	radar
television	sound track
cathode-ray tube	talkies
lantern slide	G.C.A.
photoelectric cell	

5 *Put on your thinking cap.*

What things would you regard as most important to put into a time capsule to be opened in the year 8000?

6 *Test yourself.* In your notebook, complete the following sentences with a correct word or phrase. Do not mark this book.

1. Muybridge made the first pictures of motion by allowing a ...... to trip the shutters of a series of ....

2. When developed, a piece of photographic paper or film turns ...... or ...... wherever light has struck it.

3. The light and dark colors of an object appear ...... on a photographic negative.

4. The effect of motion as you see it in the movies is an ....

5. Motion in a moving picture is due to succeeding images projected in ...... of a second or less. The eye retains the image for this length of time; this is called ...... of ....

6. The invention of radio tubes and ...... cells made sound motion pictures of the sound-on-film type possible.

7. The first mechanical talking machine was invented by ....

8. Modern tape recorders change ...... energy into ...... energy.

9. The tube that is the "seeing eye" of televison is called an .... It contains a screen or mosaic composed of thousands of ....

10. The image receiving tube in a television set is called a ...... and also a ...... tube.

11. Radar means ....

12. Radar employs radio waves that are ...... than the waves used in television.

13. Radar pips are really the ...... of waves reflected from distant objects.

7 *Adding to your library.*

Write to the Radio Corporation of America, 30 Rockefeller Plaza, New York 20, N.Y. and obtain the story of the invention of the electron microscope by Dr. Zworykin whose invention of the iconoscope and kinescope in 1924 made modern television possible.

PHOTOGRAPHY AS A HOBBY

This section is written for the beginner in photography whose aim is to be more than a shutter snapper. But this section is just the beginning of your work as an amateur photographer. After you read it, you will need to go to the other books listed at the end of the section.

There are two main steps in photography: first, take the picture; then develop it, print it, and mount it on a suitable background. The final test of your work is the satisfaction and pride you secure and the acclaim given by those who look at your pictures.

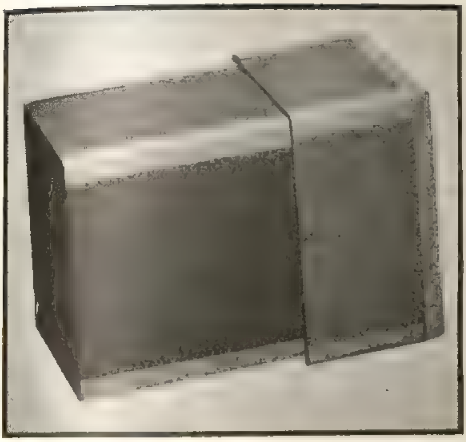
TYPES OF CAMERAS

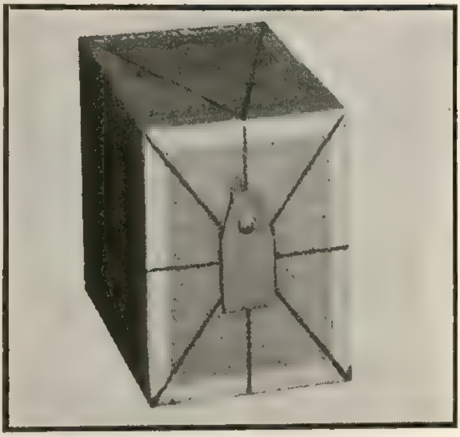
The beginner is usually limited in the choice of a camera by what he can afford. Sometimes he has no choice but to use a camera he has been given. In either case, his first job is to inspect it inside and out. Commandment number one for the photographer is: Know Thy Camera. We cannot possibly describe all the kinds of cameras in this short section but we can tell you what to look for in the one you own or hope to own.

A pinhole camera (Fig. 357) is least expensive and least useful. However, for experimental purposes, it is valuable to own one. Samples of the pictures taken with this camera are shown in Fig. 358. A pinhole camera has no lens—only a pinhole to admit light. It uses cut film which has to be loaded and removed in a darkroom or lightproof loading box each time the camera is used. Even with the fastest film, long exposures of 30 seconds or more must be made, depending upon the brightness of the subject. Naturally, the subject must be one that will remain motionless. Houses, parked cars, or airplanes on the ground are suitable subjects. Moving objects will not photograph at all, or else they will appear blurred. The only control on a pinhole camera is a shutter which you hold open for comparatively long periods of time.

Lens cameras may be classified in various ways. The simplest of all is the box camera. Like the pinhole camera, it usually has only one control—a shutter. But the shutter is operated by a spring which snaps it open and shut again in about $\frac{1}{40}$ of a second. This interval permits you to take snapshots of people and animals that are standing still. Another advantage of some cameras over pinhole cameras is the convenience of roll films, which may be loaded and unloaded in normal light. Eight or more pictures may be taken on a roll.

Folding cameras may be simple or

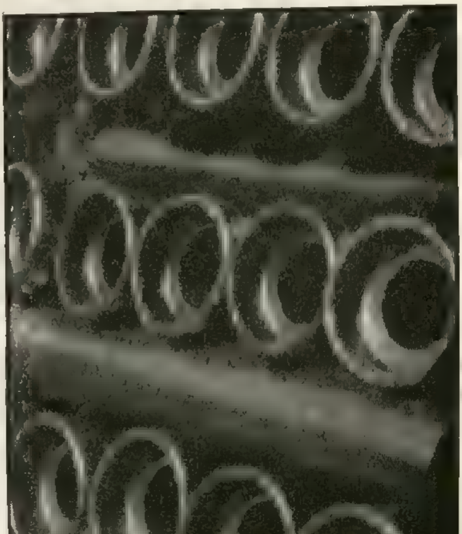




357 *A pinhole camera you can make. It will produce real photographs. The film used in this camera must be loaded into the camera piece by piece in total darkness.*

complex. As their name suggests, these cameras fold up when not in use. When open, they can be identified by the bellows which may be moved in or out for focusing. Some folding cameras are small enough when closed to fit into a coat pocket. Others are so large that they are mounted on wheels. You may have seen a view camera of this type in the studio of a portrait photographer. View cameras (Fig. 359) have ground glass screens upon which pic-

358 *These pictures were taken with a pinhole camera. Notice that only motionless objects which can be photographed with a long exposure are suitable for pinhole cameras.* (*Rochester Institute of Technology*)



359 *A view camera like this one, mounted on a tripod, is excellent for portrait work and for copying. Notice the image on the ground glass focusing screen. Can you explain why the image is inverted and reversed?* (*Burke and James*)

tures are carefully focused before the exposure is made. Some of the smaller view cameras can be used as hand cameras and because of this adaptability are very popular. As most cameras of this type are equipped with fine lenses, a range finder, and a shutter built with the care of a watch, they are expensive. For news photographers, there is nothing better.

Two other types of cameras should be mentioned. One is similar to the folding view camera in that it folds up when not in use and also permits you to focus the picture and compose it on a ground glass screen. It is the reflex camera. The other type of camera, the popularity of which amounts to a fad, is the miniature or candid camera. The best miniature cameras are small, complex, and expensive. In the hands of the expert, a fine miniature camera is a wonderful tool but we do not recommend it for the beginner. On the other hand, a simple reflex camera is excellent for the novice. Regardless of the kind of lens camera you have, you should know how to adjust it properly.

MAKING A PICTURE

There is very little difference in the mechanics of taking pictures indoors and outdoors. Chiefly, the difference is a matter of lighting. Indoors you control it entirely, outdoors you work with the lighting provided by the sun and supplement it if necessary with reflectors or flash bulbs. The whole subject of lighting is beyond the scope of this section but references 2, 3, 5, and 6 on page 516 will give you a good deal of information.

Assuming the lighting is correct, what is the next step? Compose your picture. Arrange your subject and place your camera to get the best effect.

Next you must focus your camera on the subject. Some cameras have a range finder or a ground glass screen which will help you to determine the correct focus. Sometimes it is better to have everything in focus. Sometimes a picture is improved by having only the main object in focus.

FILM

Thus far no mention has been made of film. In Chapter 28 the manner in which light affects photographic films was discussed. However, nothing was said there about the kinds of film or about the quality of negatives.

Film that is more easily affected by light is said to have a higher speed than a film not so easily affected. Slow speed films require a longer exposure or a more brightly illuminated subject than fast films. Exposure meters are designed to help you work out the proper relationship of these factors

(exposure and light) in a few seconds. Films are assigned speed ratings to correspond to the meter used. Any film rated at 100 is twice as fast as one rated 50 and requires only half the exposure time, other things being equal.

If your photography consists of copying black and white line drawings or lettering you can be satisfied with knowing only the speed of the film. But if you intend to photograph objects of many colors, you must also consider the kind of film. Orthochromatic (ôr′thō krō măt′ĭk) films are sensitive to all colors except red. Panchromatic films are sensitive to all colors including red. For this reason they must be processed in total darkness, while orthochromatic films may be processed in the light of a red safelight.

PROCESSING THE NEGATIVE

Strictly speaking, the processing of the negative begins when you click the shutter. The result of this simple act will be a negative that is correctly or incorrectly exposed. If you allow too much light to strike the negative, you will overexpose it. Your negative will be thick, dense, and heavy, and your print will have a washed-out appearance. If you allow too little light to strike the film, you underexpose it. Your negative will be thin and transparent and your print very dark.

Damage of a similar kind may be done to negatives by improper processing in the chemical solutions used to develop them. Unless you deliberately desire to underdevelop or overdevelop a negative to produce a special effect, your aim should be to leave it in the developer just the right length of time. As the developer acts faster when it is warm, its temperature must be considered and, if possible, controlled. For these two reasons, the processing of negatives is often called the time and temperature technique. Instructions accompany every box or bottle of developer for the proper processing of every type of film. The general procedure is the same in all cases.

First the film is given a bath in a developer such as D72. This takes place either in a light-tight tank into which the film has been loaded or by running the film back and forth through an open tray containing the developer. Today tank developing is preferred by most photographers. But be sure of one thing if you use a tank: The spool on which the film is loaded must be *completely* dry before another film is loaded on it. If it is not dry the coating of gelatin becomes sticky. The film sticks to the sides of the grooves on the spool. Then if you attempt to move the film the coating may be pulled away from the film. During tank development, the spool should be turned or the tank shaken constantly.

The developer completes the process begun by the light rays when they were admitted through the lens. It deposits a coating of silver on the film wherever the chemicals which coat the film were struck by the light rays. When the action of the developer has gone far enough, its action is stopped by a rinse in plain water. Next, the film is washed in a hypo bath (a solution of sodium thiosulfate) to remove from the film all the light-sensitive chemicals which were not affected by exposure to light at the time the picture was taken. This removal of the chemicals is finished when the film is clear enough to see through. However, to make sure, twice this length of time is usually allowed for the hypo bath. The acid hardener in the hypo bath acts on the gelatin coating of the film to give it hardness. The hard sur-

360

The first step in making an enlarged print is to place the negative in an enlarger like this and focus the image on a piece of paper held in the masking frame. Why is the conveniently placed timer a necessary piece of equipment?

face of the processed film resists scratching when it has dried. The film is given a final bath in running water to wash off the hypo. Then it is hung up to dry with a weight on the lower end to prevent curling as it dries slowly in the air.

PRINTS BY CONTACT OR PROJECTION

By the time you have processed your negatives, you feel the goal is in sight, but you still have to make the prints. The easiest way is to place the thoroughly dry negative against a piece of contact printing paper and insert both in a printing frame. The frame is then exposed to natural or artificial light for a suitable length of time. If you own an enlarger, you can place the negative in the path of a beam of light which is then projected like a lantern slide upon a piece of projection paper (Fig. 360). The light is turned off when the photographer believes a sufficient exposure has been made. No one can tell you exactly how long to expose your contact prints or enlargements. You will have to learn by experience how to estimate the exposure. It is always economical to use a test strip exposed for five or six different periods of time, each twice as long as the preceding one. Test strips are made by cutting print papers into one inch widths. First expose the entire strip for one second. Then cover up a portion and expose the rest of the strip for another second. Continue to cover up small portions of the strip and to expose the rest of it at intervals of 2, 4, 8, 16, and 32 seconds. This testing is

worth the effort, for in the long run it will save you time and money.

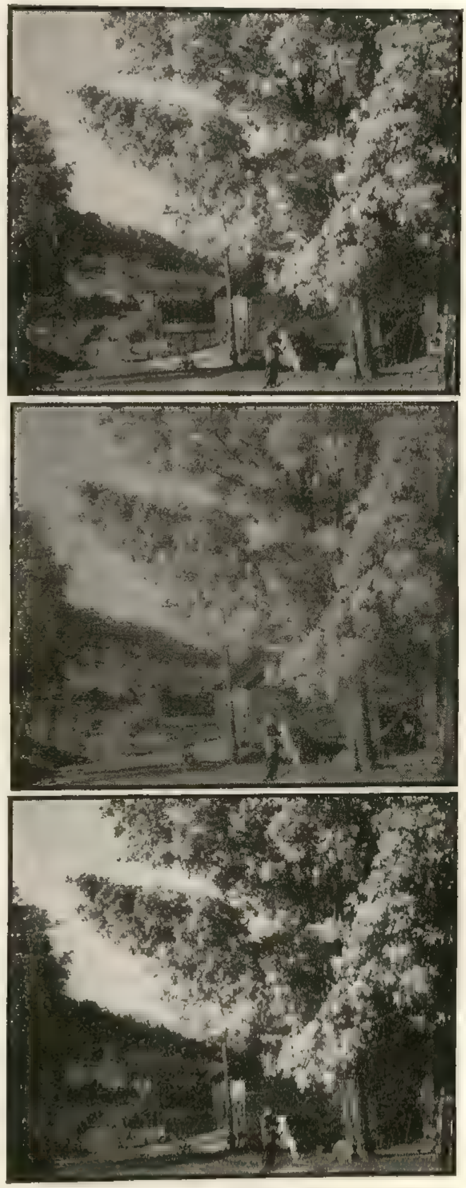
You can make the best prints by choosing the correct grade of printing paper. Printing papers are graded as hard, medium, or soft. For normal negatives, medium hard papers are used. For flat and thin negatives, use hard papers. Number 1 and 2 grades are soft, 3 is normal or medium, and 4 and 5 are hard. Fig. 361 shows the difference in prints made with the correct type of paper and those that were not.

No matter how the exposure is made, the processing of prints is similar. Trays of developer, water (stop bath), and hypo-fixing bath are arranged in a row. The print is held in the developer for the length of time recommended by the manufacturer of the developer, in the first rinse for 15 seconds, in the hypo for 15 minutes, and washed in running water for an hour, then dried between blotters. For best results the solutions should be at a temperature of 68° F. Always use fresh chemicals.

The dried print is finished by trimming or cropping away the uninteresting portions. Any blemishes may be marked out with a soft pencil. Then the print is mounted on a suitable piece of white cardboard. Never exhibit poor prints, or good ones that are poorly mounted.

A FUTURE IN PHOTOGRAPHY FOR YOU

One boy or girl reading this section will conclude that photography is hard work. Another one who has made some pictures will think it is fun. Both opinions are correct. The photographer is a craftsman and an artist, an experimenter, and a reporter. Of course he must work to achieve success, but he enjoys the satisfaction of work well done and admired. Every picture in every



361 *The correct grade of contrast paper must be used in making prints.* (Top) *If the paper is too hard the gray tones may be lost.* (Center) *If the paper is too soft the whole picture is gray and lacking in character.* (Bottom) *If the correct paper is used the print will have a complete range of black, white, and gray tones.* (*Ansco*)

magazine or newspaper brought pleasure or profit to some photographer. Certainly there are adventures ahead for good photographers. What do you think are the qualities that lead to success in photography? Do you have these qualities? If so, photography is for you. Try your hand at it.

GOING FURTHER

1 *Building a darkroom.* Write to the School Service Bureau of either the Eastman Kodak Co. at Rochester, N.Y. or the Agfa Ansco Corp. at Binghamton, N.Y. They will send you upon request the information you will need for building an efficient photographic darkroom. With the information thus obtained, construct a darkroom in your home, in the school, or in a community center.

2 *Photographs for articles.* Write an article on some aspect of photography and attempt to sell it. Start by studying the kind of pictures and ideas that are published by magazines such as the *Popular Science Monthly* or *Scientific American*. Then locate an interesting piece of craft work, or a gadget that someone has invented. Interview the person and take pictures of his achievement. In less than 500 words explain how others might do a similar job. Submit this description to a magazine with four or five excellent photographs of the project. Glossy prints 8″ by 10″ are preferred. You may be thrilled to discover your work has market value and you will be on your way to a paying pastime or possibly a career.

3 *School projects.* As soon as you get your darkroom equipment and camera set up so that you can produce good pictures, seek a school or community project. For example, you may take pictures for your school newspaper or yearbook. Various organizations in your community may welcome your assistance in the preparation of posters, favors, exhibits, etc.

Reading for the Amateur Photographer

1. Eastman Kodak Company Data Books on Photographic Papers, Lens Accessories, Lenses and Shutters, Negative Materials, Color Photography, and Infra-Red Photography. Also Developing, Printing, and Enlarging and How to Make Good Pictures.

2. *Photography*, Vol. I, published by the Navy Department, Washington, D.C., 1945.

3. *Enlarging Is Thrilling* by Don Harold, Federal Manufacturing & Equipment Co., Brooklyn, N.Y., 1945.

4. *Let's Make Pictures* by Norris Harness, the New York *Sun*.

5. *Photography for Fun* by William M. Strong, Leisure League Publishers, 1945.

6. *1001 Ways to Improve Your Photographs* edited by Williard D. Morgan, National Education Alliance, New York, N.Y., 1947.

UNIT EIGHT

INCREASING MAN'S LIFE SPAN

There is much evidence to show that we are taller and heavier than men of earlier centuries. Better diet, improved sanitation, the advance of medical science, and in general more scientific know-how about the problems of living make the difference. (*National Dairy Products*)

Dr. Semmelweiss and childbed fever

Orders were orders, especially when they came from Dr. Semmelweiss. If he said wash and rinse and wash and rinse, you did it. Life was easier for the young medical assistants in the other wards in the big Vienna hospital. But life was not easy and death was more certain for the patients in those wards.

Before Dr. Semmelweiss had come to the hospital in 1855—and even after—hundreds of mothers had died each year of something called childbed fever. The old-fashioned doctors on the staff shrugged their shoulders at the terrible loss of life in the maternity division. They said that childbed fever was due to some invisible and mysterious thing in the atmosphere. It was something, they thought, beyond their control. Semmelweiss worried and thought and experimented and the answer came to him.

The doctors themselves were infecting the mothers. They carried the infection on their hands from the sick patient to the well patient. The answer was cleanliness. Semmelweiss ordered everyone in his ward to wash his hands with soap and water and to dip them in chlorine water too. They were to wash and dip until their hands were slippery—only then could they be sure of cleanliness. The results? In two months, the death rate dropped from eighteen in every hundred to only one in one hundred.

Semmelweiss had made a really great discovery. But he was an outspoken and quarrelsome man who angered his colleagues. Especially he angered Dr. Klein, head of the hospital staff. Klein had Semmelweiss discharged from the hospital. Later he returned to Hungary, his native country, to continue his great work.

Because Semmelweiss was not too willing to write reports of his work, little was known of it outside Vienna. A few years later, a great English doctor, Joseph Lister, attacked the same problem of infection in hospitals and came to the same conclusion as Semmelweiss. The source of much of the infection was the doctor himself. Lister had a great advantage

over Semmelweiss. Lister knew that infections were caused by germs. Lister had read the great experiments of Louis Pasteur in France and of Robert Koch in Germany which showed that some diseases were caused by germs. Semmelweiss did not know about germs, but he learned from careful observation and got the desired results. Since the time of Semmelweiss and Lister, childbed fever has been gradually brought under control. Because of carelessness far too many American mothers still die in childbirth. But the cause and the prevention of many of these deaths are known. Medical science has come a long way since 1855.

Medical scientists tell us that people born in the United States after 1940 will live to the average age of 67.5.[1] If that does not seem important to you, think of those boys and girls who were born in 1830. They lived an average life span of only 45 years. Since that time medical science has learned to control many of the diseases which would kill or maim us. Much knowledge remains to be gained, however. Some scientists think that when we learn to control cancer, heart diseases, and certain diseases of old age such as hardening of the arteries, we may some day be able to live to an average age of 100 years or more.

Scientists have made a good many discoveries in their attempts to solve the problems of healthy living. We plan to show you how to use this information to keep yourself healthy. For example, we intend to take you through the physical examination which the doctor gives and to show you how a doctor gets some of his clues to the health of your body.

First things first. Before you examine the evidence gained from your physical examination, you should examine the food which builds your body. For scientists know that many substances that are in your blood today were in your food yesterday. When you have the information in Chapter 29, you will agree that the best food is needed for the best health. Later in this unit you will see how your community tries to keep you healthy by waging a constant battle against visible and invisible killers.

What you have already done and what you will do to your body in the next few years may determine your health for many years to come. You are building the foundations for your life. Whether it is to be a healthy, vigorous one is mainly up to you.

[1] Remember that an *average* life of 67.5 years for the entire population means that some people may live to 100 years or more, others no more than 30, others still less.

CHAPTER 29

THE FOOD YOU EAT

You have probably never met J. M., but you may have much in common with him. And just as this actually happened to him, it may also have happened to you.

He was a student in our school. One day we found him hurrying along in the lunchroom, tray in hand. On the tray were four steaming "hot dogs on rolls" and nothing else. As he passed, one of us asked, "Is that a balanced meal for someone who is trying to make the football team?"

"No," he said with a grin, "but I like it."

Later on we were glad to see that J. M. went back for a serving of cole-slaw and a glass of milk. He smiled and said, "Well, I balanced it."

Since J. M. was at an age when he was growing rapidly, building muscle and bone, it was especially necessary for him to eat the right foods.

Let us shift from J. M. to you. Are you as healthy as you can be? You may not be able to do much about other things that affect your health but you can do a good deal about your daily diet. Without a good diet you cannot have good health. The good diet will give you the energy you need for your activities—school, parties, sports, dancing, hiking. The good diet will help build a handsome body. The good diet will help you escape some illness.

ANALYZING FOOD

Very few people understand why they need to eat. If you were to ask them they would say, "Why, we are hungry." A few might say, "To keep healthy." Very few boys and girls realize that the right food provides materials for:

1. Energy for daily activities
2. Growth
3. Repair of muscle and other tissues
4. Efficient work of all the organs of the body

Scientists define a food as any substance that will give materials for energy, for growth, for repair, and for the efficient working of the body.

Which foods should you eat for energy, for growth, for repair—in short for the best health?

ANALYZING NUTRIENTS

Suppose we examine some of the common foods we eat for the various kinds of substances found in them.

Chemists call the basic substances of which all foods are composed *nutrients* (nū′trĭ ĕnts). All foods may be broken down into these nutrients:

1. Carbohydrates (like sugars and starches)
2. Proteins (like those in egg white, meat)
3. Fats (like those in butter, oil)
4. Minerals (like salt, iron)
5. Vitamins
6. Water

Any food may be made up of some or all of these nutrients. For instance, milk has all of the six nutrients. Although egg white is almost all protein, eggs are also good sources of all the other nutrients. On pages 536–537, you will find tables listing foods and the amounts of the different nutrients in them. Examine these tables now. Memorize five common foods that are rich in each of the nutrients: carbohydrates, proteins, fats, minerals, vitamins, and water. You will use this information when you analyze and plan your own diet.

From your earlier work in science, you probably have guessed that the nutrients themselves are made up of even simpler substances. As a matter of fact, each nutrient is made up of different elements, which are present in different amounts in each nutrient.

The carbohydrates contain the elements carbon, hydrogen, and oxygen. Fats also contain these same elements, but they contain less oxygen than the carbohydrates. Proteins, in addition to containing carbon, hydrogen, and oxygen, have nitrogen, and may have phosphorus and sulfur. The amount of carbohydrate, protein, or fat varies from one food to another. A trained food chemist can tell you what nutrients a food contains, and how much nutrient there is in a particular quantity of the food.

You can see that the complex, tasty foods you eat turn out to be a combination of chemical elements. And the storehouse for all these elements is the soil on the crust of the earth. Plants take these elements and turn some of them into carbohydrates, proteins, and fats which we use for energy, growth, and repair of our tissues.

The six nutrients can be detected by simple tests. Later you may want to go into the laboratory to use such tests to analyze any food in which you are interested. The value of these tests is clear: If we know which foods have which nutrients, we can be sure to include the nutrients in our diet in proper balance. If our diet is good, we shall have good energy, good growth, and good health.

IS THIS WHAT YOU EAT?

All four of the following meals will fill your stomach and satisfy your hunger. Which one would you choose as best for your health?

1. Bread, spaghetti with tomato sauce, potatoes.
2. Jelly sandwich, bottle of soda pop.
3. An ice cream soda, a bar of chocolate.
4. Fruit juice, lamb chop, string beans, potatoes, green salad, milk, bread and butter.

No, these aren't imaginary meals; they are common enough. How many times have a bar of chocolate and an ice cream soda served you for lunch? Of course, chocolate and ice cream taste good. But they don't build good mus-

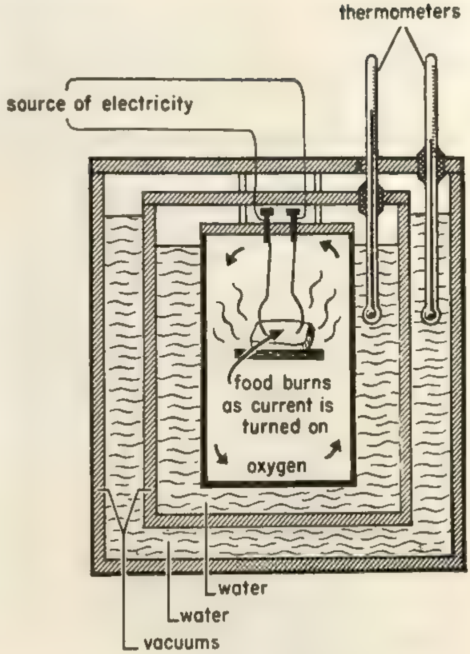
cle; neither do the first and second meals listed above. Unquestionably, the fourth meal is the best. It satisfies your hunger, is tasty, and builds good bone, muscle, and other tissues.

FOOD FOR ENERGY

All four meals described above will give you sufficient energy. In other words, these meals have enough energy food to enable you to do work.

Scientists have found that different people need different amounts of energy food. In order to discover how much energy food a person needs, it first was necessary to find some way of measuring the amount of energy that is stored in various foods. For many reasons, which we need not discuss here, it is most practical to measure the chemical energy stored in food by changing it into heat energy. What is wanted, therefore, is a measure of the amount of stored heat energy in definite amounts of common foods. Heat energy is measured in units called calories just as length is measured in units like feet and inches, or power in units of horsepower. The unit of heat energy used in food measurement is the large calorie.

A large calorie is the amount of heat necessary to raise the temperature of 1,000 cubic centimeters of water (nearly a quart) 1° centigrade.[1] In order to find the number of calories a food has, a certain quantity of it is burned in a device called a *calorimeter* (kăl′ŏ rĭm′ĕ-tẽr, Fig. 362). As the food burns in the calorimeter, it heats a certain amount of the water surrounding it. If we know the weight of the food burned and the number of degrees in temperature the water was raised, we then know how



362 *Diagram of a calorimeter. As the food burns in the inner chamber, the water outside is heated. The rise in temperature is measured by thermometers. What is a calorie?*

to calculate the calorie content of the food.

Measured this way, a pat of butter contains about 150 calories, an ordinary bar of chocolate 250, a cup of milk about 170, an apple about 100, and a slice of white bread about 60 calories. The table on page 536 will give you an idea of the calorie content of the different foods you eat. After you have examined the information in this table, sit down and calculate the approximate number of calories you had in your food today.

HOW MANY CALORIES DO YOU NEED?

Even if you knew the number of calories in any kind of food, the information would be useless unless you knew how many calories you needed.

[1] The large calorie is generally spelled with a capital C. This custom has not been followed here, however, because most popular books on nutrition do not follow it.

Your body does not supply its own energy. You get the energy you need for walking, running, and dancing from the food you eat. If you do not get enough food energy, you cannot run or swim as far or as fast as you might. If you get too much food energy, it may be stored in your body as excess fat.

A person who is very active needs more energy and, therefore, more calories than a person who is not active. You use more calories dancing or playing baseball than you do while you are reading. A truck driver needs more calories than a clerk who spends his time at a desk.

Let us suppose you weigh 100 pounds. A person of that weight needs 65 calories an hour for sleeping or just lying awake. Each hour he needs about:

70–85 for just sitting or reading
75–90 for writing
100–115 while he is typewriting
150–170 for walking
175–200 for heavy exercise

With this information, you can figure out how many calories you need on a particular day. First make a record of that day's activities. Of course, your calculation will be a rough figure, for your record will be only approximate.

Here is another quick way to figure approximate calorie needs: It has been estimated that young people need roughly 25 calories per day for each pound of body weight. If we take a hundred-pound boy or girl as an example we can see that he or she will need approximately 100 × 25 (25 calories for each pound) or 2,500 calories per day.

The National Council on Food and Nutrition has found that boys in the first year of high school generally take in an average of 3,500–3,800 calories per day. Girls, on the other hand, take less, 2,400–2,800 calories per day, because they are less active than boys.

However, some boys and girls take in more than 3,500–3,800 calories per day. A bar of chocolate alone supplies 250 calories; an ice cream soda as much as 300 calories.

How much energy is there in 2,500 calories? Here is an idea. The amount of energy in 2,500 calories is enough to permit a boy or girl weighing 100 pounds to climb 75,000 stairs each a foot high. Another idea is pictured for you in Fig. 363.

Do you want to know how many calories different people need for good health and activity? Then compare the calorie needs of different people as shown on page 538. Where do you fit in?

COUNTING CALORIES

The scientific approach to diet does not mean that you need to look up tables of figures every time you want to eat. But the information is here when you need it. However, persons who plan meals for babies, or for sick people, constantly use these tables to plan a proper diet. Normally a person will get more than the right amount of calories by following his appetite. Most active boys and girls usually get enough, more than enough, energy foods from their regular meals and in-between snacks.

Which are the best energy foods? Carbohydrates, such as sugar and starch, are the cheapest energy foods and the easiest for the body to use. Athletes, soldiers, and other very active people know that a chocolate bar, or just plain sugar, is a quick source of energy.

While fats give more than twice as much energy per gram as carbohydrates, the body cannot use fat for

energy as well as it does sugars or starches.

However, the body can store as body fat the carbohydrates which are not used for energy. Later, if necessary, this body fat can be broken down and used for energy. It is not exactly accurate, therefore, to say that those airmen and sailors who were afloat in their rubber rafts (some for 17, some for 49 days) during World War II did not have food. For some time, they were actually living on food stored in the form of body fat and other types of stored carbohydrates.

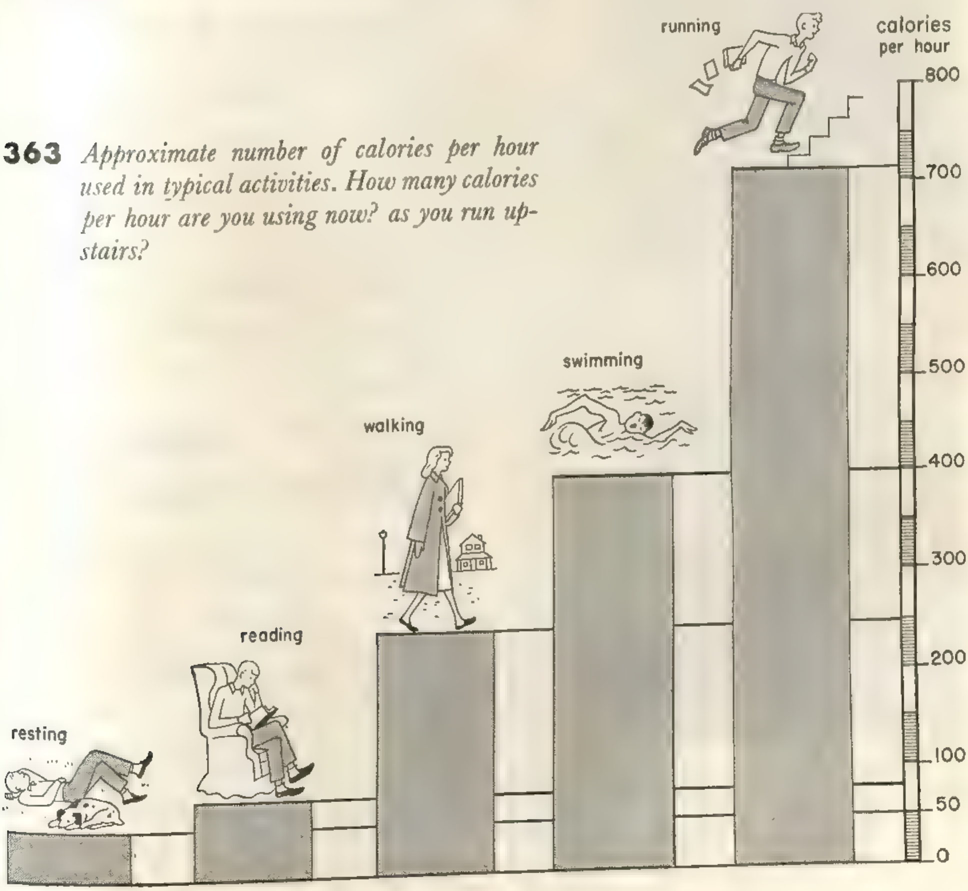
Protein, too, can yield as much energy per gram as carbohydrates but its main use is in growth and repair of the body. Protein helps build muscle, blood, and other tissues.

In general, carbohydrates and fats are used mainly for energy, and protein mainly for growth and repair.

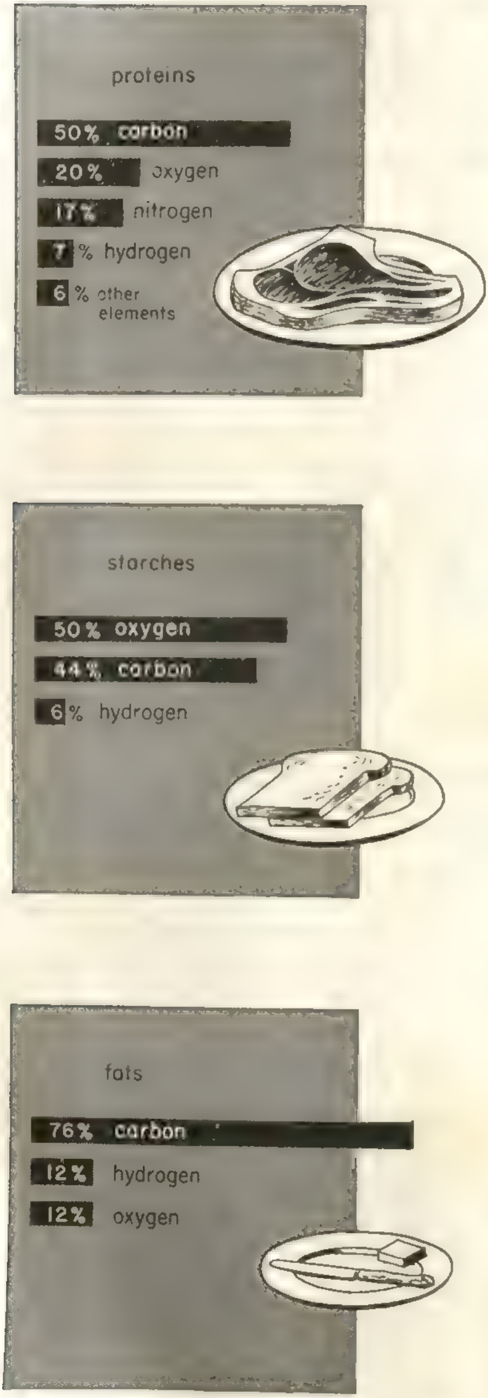
HOW MUCH OF EACH NUTRIENT DO YOU NEED?

Dietitians tell us that the Eskimo eats more fat than we do, the East Africans more carbohydrates. But the most satisfactory diet for people in the United States contains about 60–80 per cent carbohydrates, 15–20 per cent protein, and 5–10 per cent fats.

Put another way, a normal daily diet (for an active boy) should include about 400–450 grams of carbohydrates (about one pound), 100–110 grams of protein (about one-quarter pound), 60–80



363 *Approximate number of calories per hour used in typical activities. How many calories per hour are you using now? as you run upstairs?*



364 *The composition of three of the food nutrients. Compare these nutrients for their carbon and nitrogen content.*

grams of fat (four to five ounces) (Fig. 364). This does not mean that each day's diet must contain these amounts of nutrients. It is enough to average these amounts over a period of three days or so.

Scientists have found that there are several kinds of proteins and that the body functions best when it has a supply of all of them. In an experiment with mice, Dr. G. Howland Hopkins found that when their diet included corn protein as their only protein they died in 17 days. When he added other kinds of protein, the animals lived. The human body also needs proteins from different sources. A person who eats fresh vegetables, fruits, eggs, milk, and meat gets the different proteins he needs.

Examine the table on page 538. Are you getting enough protein and fat? Are you getting too much carbohydrate?

Can you stay healthy and happy if you get enough pure carbohydrates and fats for energy, with enough pure proteins for growth and repair of the body? It has been found that rats fed only these nutrients become ill and die. There is evidence to show that people on such a diet cannot stay healthy.

STARVATION ON THREE MEALS A DAY

Mahatma Gandhi, the famous leader of India's millions, used to go on a starvation strike when he wanted to force the British government to accept one of his demands. He would take water only and thus live on the stored food in his body. But as the stores of food in his body were used, he began to grow weaker. The British authorities feared that Gandhi's death in a fast might arouse his followers to violent

revenge. His demands were generally partly met. Then the Mahatma would take food.

Gandhi was starving himself for a purpose by denying himself food. But many people are starving without purpose on three meals a day. They may have enough carbohydrates, fats, and proteins, but they are starving for certain substances called *vitamins* (vī′tȧ-mĭnz) without which their bodies cannot function properly. These vitamins, unlike the other nutrients, are needed in tiny amounts. Nevertheless, when a diet is lacking in a vitamin, its absence may cause what the doctors call a *deficiency disease*. Here are some short stories of starvation caused by lack of vitamins.

JACQUES CARTIER, DR. LIND, AND SCURVY

Perhaps you have read of the sea voyages of Jacques Cartier to Canada in the sixteenth century. On his second voyage, his crew was ill from scurvy. Their gums bled and started to decay; their knee joints swelled and grew weak. Some of the men had already died from loss of blood through cuts or wounds which would not heal. A friendly band of Canadian Indians prepared a brew from spruce leaves and bark that saved the remainder of the crew from death. The crew was dying from lack of what we now know to be vitamin C.

In 1747, Dr. Lind, a sea surgeon in Britain's navy, did a remarkable experiment with twelve men who had scurvy. He gave three some vinegar, three some cider, three a mixture of mustard seed, garlic, and other herbs. These mixtures had been used for scurvy in the past but they had never been successful. To the last three men he gave lemons and lime juice. As Dr. Lind records, the men who were given lemons and limes recovered so quickly that they were "appointed nurse to the rest of the sick." The British government soon ordered that all of its men at sea be given lime juice regularly. From this time, British sailors began to be known as "limeys."

Now as a result of a great deal of scientific work, we know that the juice of lemons, limes, oranges, tomatoes, and green vegetables contains vitamin C, or ascorbic (ȧ skôr′bĭk) acid. This vitamin prevents scurvy.

EIJKMAN AND HIS BIRDS

Many scientists living in the late 1890's had begun to accept the idea that wherever there was a disease, a germ could be found that caused it. However, the beriberi which plagued the natives in China and the East Indies was widespread but apparently not a contagious disease. Dr. Eijkman (īk′-män) who was working in a hospital in the East Indies, could find no germ that caused the disease. Even wealthy natives who ate good meals of white rice [1] came to him with complaints that they were dizzy, tired, could not work, and had lost their appetites. They had also lost weight. On the other hand, prisoners in a nearby jail, on a coarse diet containing brown rice, did not have these symptoms. This one difference in diet suggested an experiment. Dr. Eijkman fed some birds unpolished or brown rice, and his control birds polished or white rice. In about 20 days, the birds fed on white rice began to show symptoms of disease. They could neither walk nor fly; they were weak; they staggered about. The birds fed on brown rice were in perfect health. When he fed his sick birds the white rice and added the

[1] The white rice has the husk of the rice grain removed.

husks which had previously been removed, they soon recovered. Clearly, the husks which were left on the brown rice contained a food element not found in the white rice.

Now through the work of many scientists who built on Dr. Eijkman's discovery, we know that green vegetables, whole grains, eggs, and yeast contain vitamin B_1 or *thiamine* (thī'ȧ-mēn). This vitamin prevents beriberi.

NIGHT BLINDNESS AND SHARK HUNTING

In Labrador, during the winter, many natives suffer from a disease known as night blindness. They cannot see well in dim light. This disease is common there only in the winter when certain foods containing vitamin A are missing. This is so because in winter most green plants which manufacture vitamin A-like substances are not to be found.

People suffering from serious vitamin A starvation find the linings of their eyelids, noses, and throats dry and uncomfortable. This drying may permit serious eye infections to start, sometimes leading to blindness. The common cold starts more easily when the membranes of the nose and throat are unusually dry.

Because we need to do away with vitamin A starvation (and vitamin D starvation), hunting the shark has become a necessary sport. Shark liver, like cod liver and halibut liver, is rich in vitamin A. This vitamin is also found in milk, butter, eggs, and green and especially yellow vegetables, like carrots and squash. If you eat these foods regularly, you will get all the vitamin A you need. You will not have to worry about the supply of shark, cod, or halibut. Where there is enough vitamin A in the diet, there are no eye infections of the type caused by lack of vitamin A, no night blindness, and fewer colds.

CROOKED OR STRAIGHT BONES

Rickets once affected rich and poor alike. The children of the rich who were kept out of the sun suffered as much as the poor children who had to live in tenement houses where the sun did not enter. The ultraviolet rays of the sun change certain substances in the skin into one form of vitamin D, the vitamin needed for growth of normal straight bones. Without vitamin D babies develop bowlegs, poor teeth, and poor bones (Fig. 365).

It has been found that if fatty foods or milk are put in ultraviolet light (or irradiated) vitamin D is formed in them. Many dairies now sell milk which has been exposed to ultraviolet light to form vitamin D. This vitamin alone will not produce good bone growth because certain minerals like calcium and phosphorus are also needed to make bones. But the body seems to need vitamin D in order to use these minerals. Exposing your body to sunshine will change certain substances in your skin to vitamin D. However, too much strong sunshine will give you a bad sunburn.

Vitamin D, like vitamin A, is found in foods like milk, butter, and fish oils. The reason vitamin A and vitamin D appear in the same foods is that both vitamins are soluble in fats and oils.

DR. GOLDBERGER AND PELLAGRA

In 1925, Dr. Joseph Goldberger of the United States Health Service was working in a certain Southern town. Before him sat a tired-looking boy. The hands he held out for Dr. Goldberger's examination were encrusted with sores. The lad could not explain his tiredness, for he got enough sleep and apparently enough food. He lacked the energy for both his schoolwork and his chores. Dr. Goldberger did not have to ask the

365
The doctor is examining this baby with a stethoscope immediately following her birth in order to make sure her heartbeat is regular and firm. The baby's health from this point on will depend in large part on the food she eats. (Pinney from Monkmeyer)

boy what he had been eating. He knew. He was looking at an advanced case of *pellagra*, a disease caused by poor diet.

Earlier in 1925, Dr. Goldberger had finished a remarkable experiment. He had asked the governor of Mississippi for permission to do a dangerous experiment on convicts, with the understanding that they were to go free after the experiment. Twelve men volunteered. They were kept in clean sanitary rooms and were fed well except that they did not get fresh vegetables, fresh meat, or milk. Within six months these men showed the red patches, the sores, and the lack of energy that are symptoms of pellagra. When fresh meat, vegetables, and milk were given to them again their symptoms disappeared.

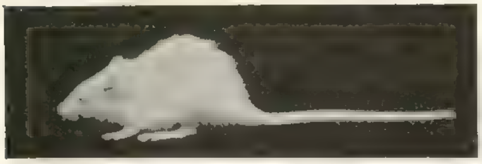
Dr. Goldberger knew, therefore, that the diet of the sick boy before him lacked fresh green vegetables, fruits, milk, or fresh meat, all of which contain a vitamin that prevents pellagra. This vitamin, we now know, is *niacin* (nī′*ă* sĭn), once known as P–P (Pellagra Preventive).

Although Dr. Goldberger did not know of niacin, his investigations had shown that green vegetables, milk, and fresh meat are necessary to a balanced diet.

MUCH FROM LITTLE

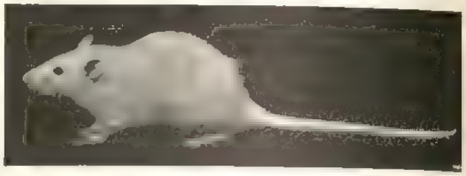
The amounts of vitamins A, B_1, C, D, and niacin needed for health are tiny.

Table X. EXPERIMENTS



Diet—no vitamin A

wheat	120 grms.
dried beef	32 grms.
starch	150 grms
salt	3 grms.
calcium carbonate	10 grms.



Same diet—with vitamin A

butter	30 grms.

Application to your living

Eat butter, milk, eggs, carrots, green vegetables, cheese, fish oils.

Diet—no vitamin B

white flour	150 grms.
butter	30 grms.
dried beef	15 grms.
starch	100 grms.
salt	3 grms.
calcium carbonate	30 grms.

Same diet—with vitamin B

yeast	5 grms.

Application to your living

Eat whole grain and cereals, green vegetables, lean meat, peas, fruits.

Notice the difference between the animals in the right and left hand columns. After several weeks on the diets listed under the pictures, the animals on the left show loss in weight, rumpled fur (a sign of an unhealthy animal) and other symptoms.

For instance, to keep in good health, we need no more than 1/28,500 of an ounce or 1/1,000 of a gram of vitamin B_1 (thiamine) a day. This is so small an amount that it can be weighed only on the finest chemical scales available. Compare this with the 100 grams or so of protein, 80 grams or so of fat, and 460 grams of carbohydrates which a man of moderate activity needs. In other words, a man needs about 460,000 times as much carbohydrate as vitamin B_1. Just the same, these tiny amounts of vitamins make the difference between good and poor health, between life and death.

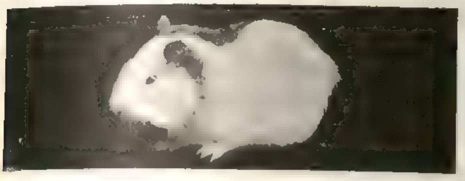
STARVATION ON A FULL STOMACH

To drive this most important idea home look at the experiments on vitamin starvation in Table X.

MORE VITAMINS

Scientists have not stopped looking for more vitamins. Only recently vitamin K, which helps prevent blood hemorrhages, has been found. The original vitamin B is now known to con-

ON VITAMIN STARVATION



Diet—no vitamin C

oats	300 grms.
bran	270 grms.
dry beans (ground)	300 grms.
butter	30 grms.
salt	10 grms.

Same diet—with vitamin C

orange or tomato juice	100 cc.

Application to your living

Eat citrus fruits, tomatoes, green vegetables, drink fruit juices.

Diet—no vitamin D

yellow corn	150 grms.
gluten flour	40 grms.
salt	3 grms.
calcium carbonate	30 grms.
no sunlight	

Same diet—with vitamin D

viosterol (containing vitamin D)	20 drops per 1,000 grms. of diet.

Application to your living

Eat milk, cheese, butter, eggs, fish, oils.

If the diets deficient in vitamins were continued, the animals would die. (Bureau of Human Nutrition and Home Economics, U.S. Department of Agriculture)

sist of several vitamins, not just one, as was originally thought. It is now known that there are several forms of vitamin D. This is also true of other vitamins. Whenever a new substance is found in the body, scientists set to work to duplicate it in their laboratories. Chemists have analyzed all the vitamins, learned their structures, and found a way to build or synthesize a good number of them.

MINERALS FOR HEALTH AND GOOD GROWTH

The minerals we need in our food are simple substances when compared with the vitamins. These minerals come in compounds called salts. One of these salts is common table salt (sodium chloride), which is present in blood and the body tissues. We also need salts containing iron, calcium, phosphorus, and iodine.

Calcium and phosphorus are needed for good growth of teeth and bones. Milk is one of the best sources of calcium and phosphorus. Growing boys and girls need at least a pint of milk each day and young children no less than a quart daily. Other sources are dairy products like cheese and eggs.

Some diseases are traced to lack of certain minerals. For instance, simple goiter, an enlargement of the thyroid gland in the neck, is due to lack of iodine. Along the seacoast, iodine (found in seaweed) is present in our food. The soil has some of the iodine salts, and the plants in turn absorb the salts. However, in the Midwestern states iodine is not present in the soil. Some Midwesterners, therefore, developed simple goiter. Goiter cases are no longer common, for salts of iodine is now put in the drinking water of Midwestern cities where goiter was found. Iodine is also supplied in table salt which is sold as "iodized salt."

Certain kinds of *anemia* (ȧ nē′mĭ ȧ) are caused by lack of minerals. In this disease, it is iron that is lacking. Iron is needed to form the *hemoglobin* (hē′mō glō′bĭn) in red blood cells. Hemoglobin is the red protein compound containing iron that carries oxygen to all our cells. Liver, carrots, spinach, and other green vegetables are good sources of iron.

MILK MAKES UP FOR MISTAKES

You must wonder just how it is possible for anyone to plan a balanced diet with so many things to take care of. But if you fill out your diet with milk, you will find that it will take care of some mistakes that may be made. Milk contains protein and fats in addition to carbohydrates. It contains a good number of the essential vitamins except vitamin C, which is present only in small amounts. It contains a quantity of minerals, the most important of which is calcium. You ought to drink at least a pint of milk a day.

BALANCED DIET = BALANCED GROWTH

For the best growth, eat the food that will give you the carbohydrates, proteins, fats, vitamins, minerals, and water you need for energy, growth, repair, and other body functions. No one, except a doctor, can tell you precisely what you should eat for healthy living. Different people need different amounts of energy. However, there is a simple dietary plan useful to most people. Check your daily diet against this plan. You should get:

1. Milk—one pint or more a day.
2. Eggs—one or more a day.
3. Meat, cheese, fish, or fowl—a serving a day.
4. Vegetables and fruits—green (lettuce, celery, cabbage, green peas) and yellow vegetables (sweet potatoes, carrots, squash, tomatoes). A serving of one yellow and one green vegetable and potato a day is desirable.
5. Citrus fruits—orange, grapefruit (whole or in juice).
6. Cereals and bread—especially bread made from whole grain (six slices with butter).
7. Water—the equivalent of six to eight glasses.

If you get these, you have no starvation symptoms whatever on three meals a day. You will be getting a balanced diet. It has the right quantities of food for energy (carbohydrates and fats) and food for growth and repair (proteins, vitamins, and minerals). If you get a balanced diet every day, you are on your way to good growth and good health (Fig. 366).

WASTING FOOD

Suppose you went to a clothing store and bought a suit with sleeves six inches too long? Then when you brought the suit home, you had it altered to fit. Doesn't that seem foolish and wasteful of material? Some people do similar things with food. They buy food only to throw some of it away.

Some people cook vegetables in water and then throw the water away. They throw away the nutrients which dissolve out of the vegetables into the water. These include the various minerals, vitamin B_1, vitamin C, and vitamin K that are dissolved in the water. They are throwing away valuable materials needed for growth and for healthy bodies.

PREPARING FOOD FOR THE GOOD DIET

Nowadays, cooking food well means preparing it so that all nutrients are saved. The water in which vegetables are boiled can be saved, cooled, salted, and peppered to taste and drunk like tomato or orange juice. Or it can be used to prepare soups, sauces, or gravies.

Pressure cooking also saves many of the nutrients. The pressure cooker uses little water; instead, the food is cooked by steam under pressure. Because food cooked this way takes less time to prepare than food cooked under atmospheric pressure, such nutrients as vitamin C are not easily destroyed. Vitamin C is destroyed by long cooking. Also, in pressure cooking, more of the nutrients remain in the food and are not lost in the water.

SHALL WE BUY VITAMINS IN PILLS OR FOOD?

Some people buy vitamin pills to make up for any lack in their diet. Medical science has not yet determined whether an excess of vitamins is harmful, although it is known that the body does not store most vitamins. Therefore, excess vitamins are not used and are lost by the body. There is some evidence that an excess of vitamin D may be harmful. However, before we come to definite conclusions that excess vitamin D is harmful, we shall need more facts about the way vitamin D is used in the body. Food chemists are still of the opinion that the best way to take vitamins is in the natural foods in which they occur.

It is still sensible to get the doctor's advice whenever you feel that you want to take any pills—even vitamin pills. Only your doctor will be able to

366
These vegetables were photographed at a county fair in New York state. Which of these items contain food elements you can name? (Standard Oil Co. (N.J.))

tell you whether you need more vitamins than you are getting in your balanced diet.

SUBSTITUTES WHICH ARE AS GOOD

It is not necessary to buy the most expensive or the most widely advertised brand of a food product. A can of brand "X" tomato juice may cost 25 cents while brand "Y" produced by another company which does not advertise as much costs 18 cents. Both may contain the same amount of vitamin C.

Expensive cuts of meat may have no more protein or other nutrients than cheaper cuts. If you are thrifty, or need to be thrifty, you will want to choose food for its nutrients. In short, you must know why you are buying the food.

For instance, inexpensive beet and turnip tops are just as useful sources of the B and C vitamins as is the costlier lettuce. Good fresh hamburger has the same nutrients in almost the same quantity as an expensive cut of steak. Cheese, eggs, liver, and fish proteins are good substitutes for the more expensive meats if you want to vary your diet. A balanced diet need not unbalance your budget.

THE GOOD DIET

Starting today keep a record of what you eat for three days. Be sure to note the amounts of food you use. Then calculate the calories you get and the amount of carbohydrate, protein, fat, minerals, and vitamins in your daily diet (pages 536–39). Remember it is necessary to see that you are getting a balanced diet over the day or so; not for every meal. However, it is a good idea to plan each meal so that it is as nearly balanced as possible.

Are you getting the diet that will keep you strong and healthy? If not, what are you going to do about it?

GOING FURTHER

1 *Analyzing vitamin content.* How much vitamin C is there in different juices? A substance which we will call indophenol[1] (ĭn′dō fē′nōl) is colored blue. Vitamin C turns it colorless. (Before the indophenol turns colorless, it may turn pink. Several more drops of juices containing vitamin C will make the pink disappear.) A test performed by one of our students showed that 27 drops of orange juice turned five cubic centimeters of indophenol (about an inch of fluid in a test tube) to white. Your teacher will give you a solution of the indophenol when you are ready for your experiment. You might compare orange juice, grapefruit juice, milk, and other liquids or juices for vitamin C content.

Plan your experiment carefully.

What apparatus will you need?

How will you measure the amount of juice you will add?

How will you be sure that you have the same amount of indophenol in each tube?

How will you record your results?

2 *How does diet affect the growth of rats?* Take two pairs of young rats just weaned. They should be of the same strain or, better yet, from the same litter. Feed them both the same diet of white bread, water, and green vegetables. To the diet of one pair add half a cupful of milk a day. Weigh them regularly every two days. What are your results?

3 *How does a lack of vitamin B_1 affect the growth of pigeons?*

1. Take four young pigeons. Feed two brown rice, the other two white (polished) rice. Be certain to give them enough water. Observe them carefully. In about three weeks, you will begin to see results. Look for signs of staggering, weakness, inability to stand.

2. After you have seen the effect of the lack of vitamin B_1, feed one of the affected pigeons some green peas. Give the other some vitamin B_1 by means of a medicine dropper. Which one recovers faster?

[1] This may be obtained under the name dichloro-benzenoneindophenol from any chemical supply house.

4 *Reports on food.* Write on these topics for your school magazine, paper, or for a report to be given in your science class.

1. Starvation on three meals a day
2. Dr. Goldberger against pellagra
3. Vitamins—vital foods
4. A good diet for me

5 *Words are ideas.* Can you use these words in a sentence which will give their meaning? Use the glossary.

food	vitamin
nutrient	carbohydrate
niacin	fat
thiamine	protein
pellagra	mineral
scurvy	deficiency disease
rickets	balanced diet
calories	

6 *Put on your thinking cap.*

1. In certain parts of the country, corn bread, molasses, and salt pork furnish the major part of the diet. What is lacking in this diet? What deficiency disease may result if this diet is not corrected?

2. During World War II, meat supplies for the civilian population were short. What substitutes would you have suggested? Why would the substitutes be needed?

3. Bill thought he was overweight. After all he weighed 10 pounds more than his brother who was a year older. Yet he ate about the same food as his brother did since they both ate at home. How might you explain the difference? What should Bill do? Eat less? Go to a doctor? Should he do nothing because he might have a different body build and thus use more food?

4. The nisei (nē′sā′), American-born children of Japanese parents (born in Japan), are almost always taller and heavier and have better teeth than do their parents. How do you explain this fact?

5. A class committee was set to do an experiment. They took eight rats and divided them as follows: four white rats with black markings on the head and legs were to be fed a diet from which vitamin A was to be omitted, while four completely white rats were to be the controls and were to be given vitamin A with their diet. Joe, a member of the committee, thought this was a poor experiment. What do you think his reasons were?

6. A scientist suspects that green vegetables contain a vitamin that helps growth. He has 200 rats with which to experiment. Plan an experiment that would help him get the facts he needs.

7 *Adding to your library.* Here are some references that will help you improve your own diet.

1. *Hunger Fighters* by Paul de Kruif, Harcourt, Brace, 1928. This is one of the most fascinating books about the scientists who have fought hunger. You won't be able to put it down.

2. *Trail to Light* by Robert E. Parsons, Bobbs-Merrill, 1943. This is a biography of Dr. Joseph Goldberger. Pages 279–327 tell of his work on pellagra.

FOOD TABLES FOR THE AMATEUR DIETITIAN[1]

THE SOURCES OF YOUR CALORIES, CARBOHYDRATES, FAT, AND PROTEINS

Food	Calories	Carbohydrates (per cent)	Fat (per cent)	Proteins (per cent)
Apple, raw, 1 large, 3″ diam.	97	15	0.4	0.3
Bacon, 5″ strip, crisp	31	2	27	14
Banana, 1 medium	99	23	0.2	1.0
Beans, navy, pea, kidney, ½ cup	105	62	2	22
Beans, snap, ½ cup	42	8	0.2	2
Beef, 1 slice 3″ × 2″ × ½″	233		16	23
Bread, enriched white, 1 slice	65	52	2	8
Bread, whole wheat 60%, 1 slice	72	46	3	9
Butter, 1 pat	73	0.4	81	0.6
Cabbage, fresh, ½–¾ cup, shredded	15	5	0.2	1
Carrots, raw, 1 large, ¾ cup (cubes)	45	9	0.3	1
Cheese, American Cheddar, 1 oz.	112	2	32	24
Chicken, roasted, 3 slices, 3½″ × 2½″ × ¼″	193		9	28
Codfish, 1 cake, 2½″ diam.	122	16	11	11
Egg, whole, 1 medium	79	0.8	12	13
Frankfurter, boiled, 1 average	121	3	14	15
Grapefruit, ½ small	44	10	0.2	0.5
Ice cream, plain, ⅙ quart	210	21	12	4
Lamb chop, shoulder, 1 average chop	245		22	17
Liver, beef, fried, 1 average slice	82	8	8	25
Milk, whole, 6 ozs.	123	4	3	3
Orange, whole, 1 medium	76	11	0.2	0.9
Potato, white, cooked, 1 medium, in skin	129	19	0.1	2
Spinach, fresh, ⅔ cup	25	3	0.3	2
Tomatoes, canned, ½ cup	21	4	0.2	1

[1] Adapted from "Food Values of Portions Commonly Used" by A. de P. Bowes and C. F. Church. See Tables on the following pages for sources of vitamins and minerals and daily needs for different kinds of work. On page 538 you will find your daily requirements in carbohydrates and proteins.

In the units represented on the following pages I.U. = International Unit, mg. = 1 milligram (1/1000th of a gram), mcg. = 1 microgram (1/10,000th of a gram). On the basis of these units boys and girls need

FOOD TABLES FOR THE AMATEUR DIETITIAN

THE SOURCES OF YOUR DAILY VITAMINS AND MINERALS

Calcium (mg.)	Iron (mg.)	Phosphorus (mg.)	Vitamin A I.U.	B_1 Thiamine (mcg.)	B_2 Riboflavin (mcg.)	B_6 Niacin (mg.)	C Ascorbic acid (mg.)	Vitamin D I.U.
9	0.5	15	135	60	30	0.3	8	
2	0.1	16		60	10	0.3		
8	0.6	28	430	90	60	0.6	10	
44	3.1	139		180	72	0.6		
65	1.1	44	630	80	100	0.6	19	
13	3.5	250		122	153	5.3		
14	0.5	25		60	37	0.6		
14	0.6	42		84	49	0.9		
2		2	330		1			4
23	0.3	16	40	35	30	0.1	26	
39	0.8	37	12,000	70	60	0.5	6	
247	0.2	173	493	11	142			
22	2.7	305		92	214	10.2		
11	0.8	71	130	44	49	0.7	?	5
27	1.4	105	570	60	170			45
5	1.4	98		111	135	1.2		
17	0.3	18		40	20	0.2	40	
132	0.1	104	540	40	190	0.1		
9	2.3	168		153	196	4.4		
6	6.1	187	9600	115	1190	6.8	?	23
212	0.1	167	288	72	306	0.2	2	4
50	0.6	35	285	120	45	0.3	74	
17	1.1	84	30	168	55	1.6	17	
	3.0	55	9420	120	240	0.7	59	
11	0.6	27	1050	50	30	0.7	16	

Vitamin A, 5,000; Thiamine (B_1), 1,500; Riboflavin (B_2), 2,000; Niacin (B_6), 15; Ascorbic acid (C), 85. In the minerals, you will need Calcium, 1,350 mg.; Iron, 15 mg.; Phosphorus, quantity needed exactly is unknown. A diet such as suggested on page 532 furnishes a sufficient amount of phosphorus as well as sufficient quantities of vitamins and minerals as listed above.

FOOD TABLES FOR THE AMATEUR DIETITIAN

DAILY CALORIE NEEDS FOR DIFFERENT KINDS OF WORK

Kind of work	CALORIES NEEDED For men of average weight (154 lbs.) ages 20/60	 For women of average weight (130 lbs.) ages 20/60
Very active work moving men, active soldiers, caisson work, any work involving heavy lifting or pulling	4500	3000
Fairly active work hiking (with full knapsack), marching, salesmen (door to door), any work involving walking with moderate loads	3000	2500
Light work selling behind counter, typing, active office work, any work in which the person is seated but does move arms and legs and walks about freely; heavy lifting is not involved	2700	2300
Sedentary work office work, information booth, any work in which the person is seated and which involves little arm or leg movement	2400	2100

DAILY DIET FOR A MODERATELY ACTIVE MAN

Kind of nutrient	In units
Energy (carbohydrates and fats)	3000 Cal.
Protein (varied)	70. g.
Calcium	1. g.
Iron	12. mg.
Vitamin A	5000 I. U.
Thiamine (vitamin B)	1.5 mg.
Riboflavin (vitamin G)	1.8 mg.
Niacin	15. mg.
Ascorbic acid (vitamin C)	75. mg.

FOOD TABLES FOR THE AMATEUR DIETITIAN

APPROXIMATE CALORIE NEEDS FOR DIFFERENT ACTIVITIES[1]

Activity	Calories per pound of weight per hour
Bicycling (moderate speed)	1.1
Bicycling (racing)	3.4
Carpentry, heavy	1.0
Dancing	1.7
Dishwashing	0.5
Dressing and undressing	0.3
Eating	0.2
Playing ping-pong	2.0
Running	3.3
Sawing wood	2.6
Sitting quietly	0.2
Standing relaxed	0.2
Swimming	3.6
Typewriting rapidly	0.5
Violin playing	0.3
Walking (3 miles per hour)	0.9
Writing	0.2

[1] Adapted from *Foundations of Nutrition* by Mary Swartz Rose, Macmillan, 1938, pp. 606–07. Reprinted by permission.

Using this table: Suppose you weigh 120 lbs. For a good walk you will need 120 × 0.9 (see above) = 108 calories per hour. Add to this 65 calories per hour for body activities such as breathing, digesting food, etc. Total = 173 calories. Remember this is approximate.

COMPARING DAILY VITAMIN NEEDS

	Vitamin A I.U.	Thiamine mgs.	Riboflavin mgs.	Niacin mgs.	Ascorbic acid mgs.	Vitamin D I.U.
Girls						
13 to 15 years	5000	1.4	2.0	14	80	?
16 to 20 years	5000	1.2	1.8	12	80	?
Boys						
13 to 15 years	5000	1.6	2.4	16	90	?
16 to 20 years	6000	2.0	3.0	20	100	?

CHAPTER 30

YOUR BLOOD WILL TELL

In some Chinese communities, doctors are not paid for visits to sick people. They are paid, it is said, only when their patients are well. True or not, the practice is a good one. For if you think about it for a moment, one of the best ways to keep the doctor away is to visit him regularly when you are well.

There, in his office, he will examine your body carefully. He may find something which needs watching, or he may catch a disease in time. Most of the time, however, he will send you away smiling, safe and secure in the knowledge that you have a fine body. Have you had your health checked this year?

The doctor gets his clues to your health by using many instruments. One of these is the *stethoscope* (stĕth′ō skōp). With it he listens carefully to your heartbeat. And what he hears may tell him whether your blood is circulating easily and quickly so that your body cells are getting food nutrients and oxygen readily. For your cells can get nutrients and oxygen only through the blood which your heart pumps through the body.

The doctor may check up on the clues he obtained through his stethoscope by having your blood examined under the microscope. He may have some careful chemical tests done in the laboratory.

You have heard the expression "blood will tell." Ordinarily it means: A person's heredity will determine success or failure. You have already learned that blood does not determine one's heredity (Chap. 1). But in another and literal sense blood does tell. It tells a doctor a great deal about a person's health.

THE MAKE-UP OF THE BLOOD

What would an examination of a smear of normal blood reveal on a slide under the microscope? Just what you see in Fig. 367.

BLOOD CELLS

Notice the numerous round cells; these are the red blood cells. There are about five million of these red cells in a very tiny drop of blood (a cubic millimeter). They contain a substance which takes on a deep red color when it

combines with oxygen. This substance is called hemoglobin. Red blood cells have no nucleus.

The other cells in the blood are the white blood cells. They do have a nucleus but they have no hemoglobin. Normally there are 5,000–7,000 of these white blood cells in a drop of blood. Unlike the red blood cells, white blood cells can move about much as an amoeba does. If you were watching such a cell move, you would see it send out a short bulge, then another, and another. Not only are these bulges useful for moving about, but they can engulf any microscopic particles like bacteria that get into the blood.

BLOOD PLASMA

What you don't see on the slide, strangely enough, is one of the most important parts of the blood. It is a straw-colored liquid in which the red and white blood cells float. It is called the *plasma* (plăz′mȧ). You probably have heard that during the last war plasma was given to soldiers suffering from shock due to severe wounds.

To sum up, blood—all human blood—contains red and white blood cells in plasma. What do these cells and plasma do for your health?

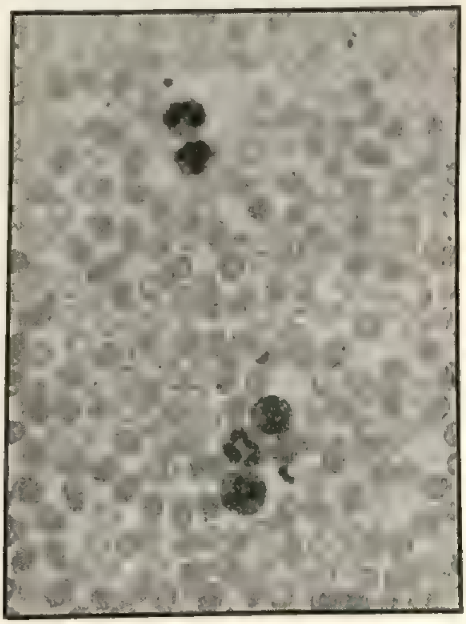
HAVE YOU THE RIGHT NUMBER OF BLOOD CELLS?

Have you ever had your red and white blood cells counted? An experienced laboratory technician does this quickly and accurately. A drop of blood is taken from your fingertip and the cells are counted in a special chamber under the microscope. The blood count reveals several important facts.

As you remember, white blood cells attack any bacteria that enter the body. The white blood cells increase in number as they swarm to the attack. As you know, there are about 5,000–7,000 white blood cells in a large drop of blood. Suppose the number goes up to 12,000. This may mean that bacteria have entered the body and that great numbers of white blood cells have been released by your body to attack the invaders. In appendicitis, for instance, the number may go up to 12,000 or as high as 20,000. On the other hand the normal number of white blood cells usually indicates that the person being examined has no infection.

The red blood cells tell another story. As you remember, there are normally five million red cells in a large drop of blood. They contain the red substance, hemoglobin, which com-

367 *A slide of stained human blood cells. The five large cells (in groups of three and two) with dark contents are white blood cells. The other cells are red blood cells. Which cells are most numerous? Which contain hemoglobin? (General Biological Supply House)*



bines with oxygen and carries it to every cell of the body where it unites with food and supplies energy. Therefore, when the number of red blood cells is low, the human body cannot get the amount of oxygen it needs for good health and the disease anemia results.

THE RIGHT KIND OF PLASMA

You should not forget that the blood plasma is just as essential for your good health as the red and white blood cells are. Dissolved in the plasma are all the food nutrients used for energy and growth: carbohydrates, proteins, minerals, vitamins.

This isn't all. The plasma also has substances which help destroy different kinds of bacteria. Substances which do this are called *antibodies*. One kind of antibody destroys typhoid bacteria. Another counteracts the poisons made by diphtheria germs.

In brief, the plasma contains almost every kind of substance found in your body. A blood chemist can analyze your plasma and tell you what is in it. In general, he finds four kinds of substances in it: nutrients, antibodies, wastes, and certain special substances used in blood clotting and in growth. One special substance which helps clot your blood is called *fibrinogen* (fībrĭn′ō-jĕn). When you have a cut the fibrinogen is turned into a substance called *fibrin*. This substance consists of small fibers which enmesh each other and form a clot which plugs up the cut and keeps bacteria out. Another group of special substances carried by the blood, called *hormones* (hôr′mōnz), help regulate your height, the growth of your bones, your weight, and even your behavior. For instance, a growth hormone is partly responsible for body growth. This hormone is produced by a gland found on the lower surface of the brain. Too much growth hormone may produce a giant. Too little may result in producing a midget.

Obviously, if the plasma lacks any of the four kinds of substances, poor health may result. For instance, too much sugar in the blood may mean that the person has diabetes. Too little iron, as you remember, is one of the causes of anemia.

Do you know how substances like sugar and iron get into the plasma? Let us go into the laboratory and find out.

TRANSFORMING THE FOOD WE EAT

The food which you chew and swallow finds its way into a long food tube about 25 feet in length. Somehow the food must get out of this food tube into your blood plasma. How is it done? What happens to the food after you swallow it?

ACTION IN THE MOUTH

Let us begin with the first part of the food tube, the mouth. Our experimental material is an ordinary soda cracker. This time don't eat it; divide it into four parts. First test one part for the presence of starch and simple sugars. With iodine the cracker turns blue, showing the presence of starch. But when one part of the cracker is boiled with Benedict's solution, it does not turn green or red as it would if simple sugars were present. This shows that these sugars are not present in the cracker.

Now take one-quarter of the cracker and chew it carefully. Don't swallow it. Instead, after a few minutes, deposit this chewed mixture in a test tube.

Now test this cracker which you have chewed and mixed with saliva with Benedict's solution. It turns a brick red. Simple sugars are present.

Check on this. Test your saliva alone with Benedict's solution. The solution does not turn red. Sugar is not present in the saliva. Now grind up the last quarter of the cracker and add an inch of saliva (collected in a test tube) to it. Shake up the mixture and keep the tube warm in the palm of your hand. After five minutes, test for sugar. The brick red color indicates that sugar is present. Possibly you will be ready to state that something in the saliva may be responsible for changing starch to sugar. Your hypothesis is correct. Biologists have discovered that saliva contains a substance called an *enzyme* (ĕn′zīm). The special enzyme which changes starch to sugar in the mouth is called *ptyalin* (tī′ȧ lĭn).

ENZYMES IN THE FOOD TUBE

Scientists have further discovered that enzymes are produced not only in the mouth but also in the stomach and small intestine. The structures which produce these substances are called glands. Scientists have been able to extract these enzymes from the glands of cattle so that enzymes can be purchased at a drugstore on a doctor's prescription.

All of these enzymes break down complex substances into simpler substances. The powerful enzymes of the stomach and intestines break down complex food nutrients, proteins, fats, and starches into simple substances. This process by which complex food nutrients are broken down into simple nutrients is called *digestion*.

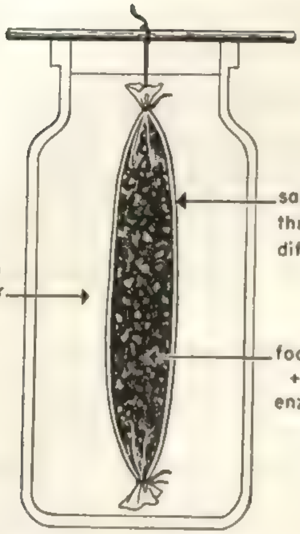
The digestive enzymes do their work aided by certain substances which seem to be needed for their action. For instance, digestion by the stomach enzyme *pepsin* is carried on fastest in the presence of a small amount of hydrochloric acid. The needed hydrochloric acid is manufactured in the stomach walls and released as it is needed. Digestion by the enzymes in the small intestine, however, is fastest in the presence of an alkaline substance found in the intestine.

MAKING AN ARTIFICIAL FOOD TUBE

In 1822, Dr. William Beaumont, attending a wounded woodsman, had the rare privilege of observing digestion in the human stomach. The wound healed in a peculiar way and left an opening in the stomach which permitted Dr. Beaumont to see what was happening inside. Thus Dr. Beaumont was able to observe and describe what the enzymes of the stomach did to food. He saw the flow of digestive juice manufactured by the stomach glands as food entered the patient's stomach. He also saw this juice, called gastric juice, turn the food into a murky fluid. Of course you haven't a wounded woodsman handy to help you observe food tubes. But we can make an artificial food tube in which we can duplicate some of the processes of digestion (Fig. 368).

Let us take a long sausage skin or frankfurter skin and tie it at one end.[1] This will represent a human food tube with its mouth, stomach, and intestines. Into this tube, we will place parts of an ordinary meal: a piece of meat, some potato, bread and butter, milk, vegetables, and water. Naturally, before we put this mixture into the tube, we chop it up well and mix it thoroughly to be sure that it is in somewhat the

[1] Not all sausage or frankfurter skin is suitable for this demonstration. The skin must be of a sort to allow diffusion to occur.



368 *A diagram of a demonstration of digestion. If the sausage skin contains starch, what substance will diffuse into the warm water? See Table XI.*

same condition as food is when it reaches our stomachs. Now we add the digestive enzymes found in the intestine to the food tube crammed with the meal of proteins, fats, and carbohydrates. The enzymes found in the upper intestine are produced by a digestive gland called the *pancreas* (păn′krē ȧs). The pancreas is found near the beginning of the small intestine and joins the intestine by means of a small tube. It produces enzymes that can break down all the food nutrients. We also add a small amount of sodium carbonate which is needed for the enzyme to act. Of course, we keep the artificial food tube in a container of warm water at body temperature, about 37° centigrade (98.6° F.).

Within 48 hours or so, the food in the artificial food tube seems to have dissolved. Only a murky fluid is left in it.

Table XI. THE ENZYMES WHICH DIGEST YOUR FOOD

Enzyme	Place produced	What it does
Ptyalin (tī′ȧ lĭn)	Mouth	Breaks down starch to sugar in the mouth
Pepsin (pĕp′sĭn)	Stomach	Breaks down proteins to simpler substances
Trypsin (trĭp′sĭn)	Pancreas (păn′krē ȧs) (a gland near the small intestine). The pancreatic juice is sent into the small intestine	Breaks down protein to soluble amino acids
Steapsin (stē ăp′sĭn)	Pancreas	Breaks down fats into fatty acids and glycerin
Amylopsin (ăm′ĭ lŏp′sĭn)	Pancreas	Breaks down any undigested starches into glucose
Enzymes in intestinal juice	Intestine	Breaks down any undigested food
	RESULTS OF DIGESTION	
All enzymes	In the alimentary canal	Produce soluble materials: Glucose from carbohydrates Amino acids from proteins Fatty acids } from fats Glycerol }

What has happened to the complex, solid, food nutrients? They have been digested. The enzymes we added have broken them down into simple substances which are now dissolved in the fluid in the artificial food tube.

Where would you expect to find some of these nutrients? If you test the murky fluid in the artificial food tube, you will find simple sugars, digested proteins, and digested fats. Since these digested substances are simple in nature, they can dissolve. As you remember, dissolved substances can diffuse through membranes. And this is exactly what has happened. After the digested foods dissolved in the fluid in the artificial food tube, they diffused through the membrane (sausage membrane) of the food tube into the container of warm water (Fig. 368).

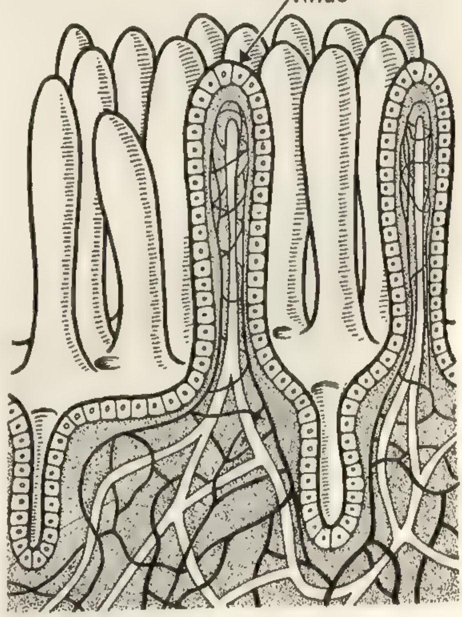
What has happened in this artificial food tube resembles the process of digestion that goes on daily in your own food tube. Naturally, what happens in your digestive tube is more complex. Enzymes are, however, constantly being poured into it by your glands (Table XI). These enzymes change the complex insoluble foods you eat into soluble, simple nutrients which can diffuse through the membrane of your food tube. Digestion, therefore, readies the food for passage through the membrane of the food tube. But, once past the membrane, where do the nutrients go?

FROM THE INTESTINES INTO THE BLOOD

Right now, food substances and oxygen are being distributed by your blood stream to every part of your body. Food and oxygen are carried to your eyes and eye muscles, to the muscles that are helping you hold this book, to your brain, to your lungs, even to your heart that is pumping your blood. How do the dissolved nutrients reach the blood stream?

You know that soluble nutrients leave the intestine and go through the membrane of the intestine. However, if we examine this membrane, we find that it is not smooth at all. It is covered on the inside with tiny tubelike structures called *villi* (vĭl′ī, Fig. 369). To get an idea of the villi in the intestine you might visualize a long cylinder (the intestine) studded on the inside with millions of microscopic projections, like tiny test tubes (the villi).

Each *villus*, however, has more to it than a membrane. In each villus, there is a network of the tiniest blood vessels in the body, called *capillaries* (kăp′ĭ lĕr′-ĭz). These tiny tubes are filled with blood (Fig. 369). They have thin mem-



369 *Villi, here much magnified, line the small intestine. The dark lines within the villus are capillaries; the white club-shaped vessel in the center of the villus is a lacteal.*

branes through which digested food easily diffuses. Shortly after the digested food diffuses through the membrane of the villus, it reaches the thin walls of the capillaries. The simple proteins and sugar diffuse through the capillary wall into the blood and are absorbed there. Digested fats, however, are absorbed into the special structures in the villi, called *lacteals* (lăk′tē ǎlz). Eventually, the digested fats reach the blood. This diffusion of digested food into the villi is called *absorption*.

Examine the diagram of the villus (Fig. 369). Notice the "space" between the membrane of the villus and its capillaries. In your body, this "space" is not a space at all; it is filled with a colorless fluid called *lymph* (lĭmf). The lacteal is also filled with lymph. Absorption, therefore, takes place through the villus membrane into the lymph, then through the walls of the capillaries inside the villus.

You may well ask whether all absorption takes place through the villi of the small intestine. Why not through the gullet or the stomach? There is evidence to show that small amounts of grape sugar (glucose), alcohol, and water are absorbed through the membrane of the stomach. It is the intestine, however, which has the structures, the villi, specially fitted for absorption. When scientists find a structure fitted for a special job, they say it is adapted to that task. For instance, the teeth are adapted for cutting and chewing, the stomach, with its tough muscles, for churning and mixing. The intestine, with its villi, is adapted for absorption.

REACHING THE BODY CELLS

Food would be of little use to you if it were to remain in the capillaries of the villi. Of course, it doesn't. It is brought to every cell by your blood. How?

Feel your pulse by placing the tips of your two middle fingers on your wrist. Count the beat per minute. You will probably find that it beats anywhere from 65 to 85 times per minute. You may not realize that the beat felt at the wrist starts at the heart almost three feet away.

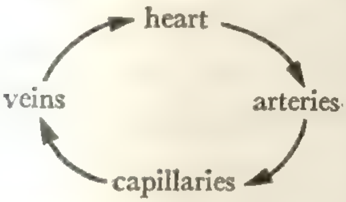
The heart is a pump made of thick muscle. It does not pump oil or water; it pumps blood to every part of the body. It never stops pumping during your lifetime. Its steady pumping takes the blood from the capillaries of the villi and sends it to larger blood vessels. Just as small side roads or streets run into main streets and finally to the town square, so capillaries from the villi lead to larger vessels which lead finally to the heart. Where does the heart send the blood it receives?

CIRCULATION IN THE ARM

Suppose you examine the circulation in one of your limbs, let us say, your left arm. The bluish blood vessels you see are *veins*, which carry blood to the heart. Your other set of blood vessels, the *arteries*, is buried deeper in your tissues.

The heart pumps the blood into the main artery of the arm. Like all the arteries, this one takes the blood away from the heart. From the main artery of the arm, smaller arteries branch out. These in turn branch again and again into smaller and smaller arteries. Finally from the smallest branches of the arm artery come the tiny capillaries. These tiny, thin-walled capillaries, as shown in Fig. 369, form a complete network reaching the cells of your arm. For instance, when you prick your finger, the blood comes out of these

capillaries. After the capillaries have reached the body cells, they join together to form the beginning of the system which returns the blood to the heart. These small blood vessels join to form larger veins, which in turn join to form still larger veins. The largest veins eventually reach the heart and pour the used blood into it. So you see why we say the blood circulates. The blood vessels form a closed circuit. Thus:



Arteries always carry blood away from the heart. Veins carry blood back to the heart.

SEEING BLOOD CIRCULATE

You can actually see the capillaries in the web of the foot of a frog, or the tail of a tadpole, or the tail of a fish. You may place a small fish, such as a goldfish, on a flat piece of glass. To keep the gills moist, place a flat piece of wet absorbent cotton over the head of the fish. Now place the glass plate on the stage of a microscope. Be sure to cover the tail of the fish with a slide. Using the low power of the microscope, focus on the tail. Observe carefully.

Do you see small round bodies moving in the blood vessels? These are usually the red blood cells which, you remember, carry oxygen to all the other cells of the body. Notice how the smaller blood vessels join to form larger ones. You will also notice the same thing in the webbed foot of the frog, or the tail of the tadpole. You would notice the same thing in yourself if parts of your body were transparent. Many experiments have been done on the circulation of animals like fish, amphibia (frogs, salamanders), reptiles (turtles, snakes), birds, and mammals (dogs, men). All these experiments tell us that in these animal groups the blood circulates through a system of closed blood vessels.

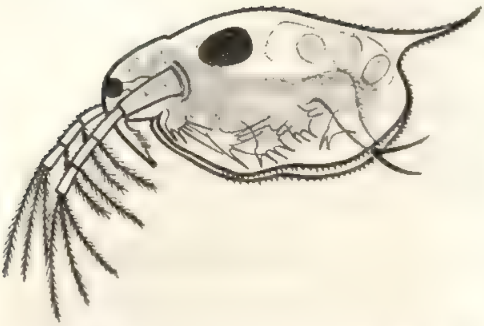
HOW FAST DOES THE BLOOD CIRCULATE?

An interesting experiment dramatizes the answer to this question. A harmless chemical which has a peculiar taste is injected into the vein of a person's foot. A stop watch is set. As soon as the person reports that he tastes the chemical, the watch is stopped. We know that the chemical must have traveled from the foot to the tongue where the substance was tasted. No matter how many times this is done, we find it takes about 11 to 13 seconds. It takes about the same time for blood to get back to the foot. So the entire circulation from the foot vein to the main body vein, to the heart, to the lungs, back to the heart, to the main body artery, to the tongue artery, to the body artery, to the foot artery, to the foot vein, takes about 25 seconds.

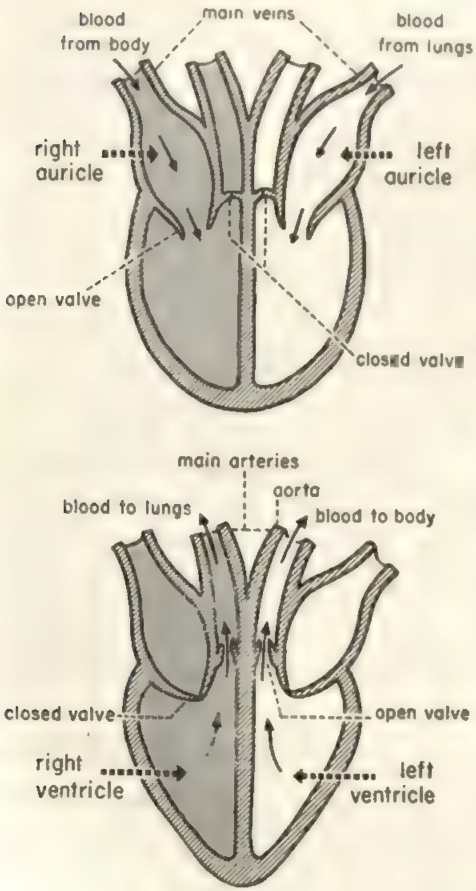
Calculate about how many times the blood circulates in an adult human body every 24 hours. An adult has about 5 to 6 quarts of blood in his body. Every 25 seconds, the entire 5–6 quarts circulate in the body. How much blood does the heart pump in 24 hours?

PUMPING BLOOD TO ALL CELLS

It is hard to find an animal transparent enough to permit examination of its heartbeat under the microscope. But the small water flea, Daphnia, may do. You can find it in almost any pond during early spring, summer, and autumn. It is about the size of a pin-



370 *Daphnia, the common water flea. The large dark oval structure is the heart.*



371 *A diagram to show how the heart works. What keeps the blood from rushing back into the auricles? Why is the left side of the diagram shaded differently from the right side?*

head (Fig. 370). Its small heart beats so quickly that you cannot count the heartbeat. But the heart of a Daphnia is a very simple affair compared with yours.

THE HEART

One practical way to learn something about the structure of your heart is to dissect a sheep's heart. The hearts of all mammals are very much alike.

By cutting the sheep heart in half from the blood vessel end to the tip, you will be able to see a thick wall which separates the heart into left and right chambers (Fig. 371). Picture, in your mind, the heart as it receives blood. It will receive the blood from the large veins which enter on the right side of the heart into a thin-walled chamber called the right *auricle* (ô'rĭ k'l). This right auricle collects blood from the entire body. It leads to a thick muscular chamber called the right *ventricle* (vĕn'trĭ k'l). The auricle opens into the ventricle by means of a valve (Fig. 371). Imagine one room above another connected by a trap door (the valve) which seals the upper chamber, and you will have a very rough idea of the position of the auricle and the ventricle. If you examine the right ventricle, you will see that a large blood vessel, an artery, leaves it (Fig. 371). This artery will take blood to the lungs. In the lungs, the blood will lose carbon dioxide and gain oxygen. Now imagine this bright red blood, loaded with oxygen, coming back to the heart from the two lungs. These blood vessels from the lungs enter the left auricle. The left auricle is opposite the right auricle (Fig. 371).

From the thin-walled left auricle, the blood enters the left ventricle through another valve. This thick-muscled chamber pumps blood out into the

body, through the largest, strongest artery in the body, the *aorta* (ȧ ôr′tȧ, Fig. 371).

THE PLAN OF THE HEART

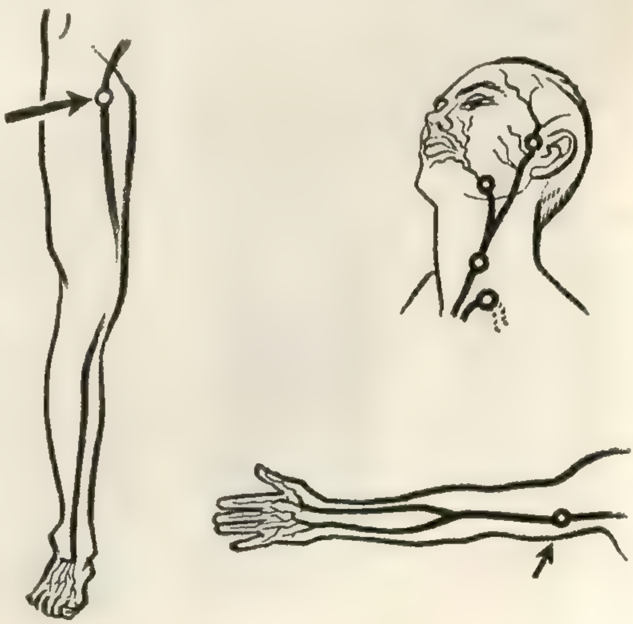
Now review the plan of the heart. The human heart is about the size of a fist. There are four chambers: two auricles and two ventricles. The auricles are in front of the ventricles and are connected to them by strong valves. The blood flows from the body's veins to the right auricle, then into the right ventricle, and out of the heart to the lungs. Then it flows from the lungs to the left auricle, then into the left ventricle, and out of the ventricle into the aorta. The auricles are the receiving stations; the ventricles are the pumping stations.

What prevents the blood from being pumped back into the auricles? If you examine the auricles of any heart, you will be able to find whitish tough strands attached to thick flaps which separate the auricles from the ventricles. These are the heart *valves* (Fig. 371). As the ventricle contracts, the valves close and the blood does not back up into the auricles. Instead, the blood goes into the arteries. Even the aorta and the veins have valves which prevent the blood from backing up.

ARTERIES AND VEINS

If the arteries were tubes as rigid as glass tubes, you could not feel the pulsing of the blood. The walls of the arteries are thick with elastic tissue and muscle cells which are relaxed as the blood is pumped into them and contract as the heart relaxes. Feel the "pulses" in the arteries in your temple, neck, heel, arm, and wrist. Feel the blood vessels relax and contract.

It is because arteries expand and contract that a cut artery spurts blood. If an accident occurred and an artery were cut, where would you exert pressure to stop bleeding? If it were a cut near the surface, pressure with the fingers on a piece of sterile gauze placed over the cut would be enough. For other cuts, you might have to exert pressure at "a pressure point" (Fig. 372) between



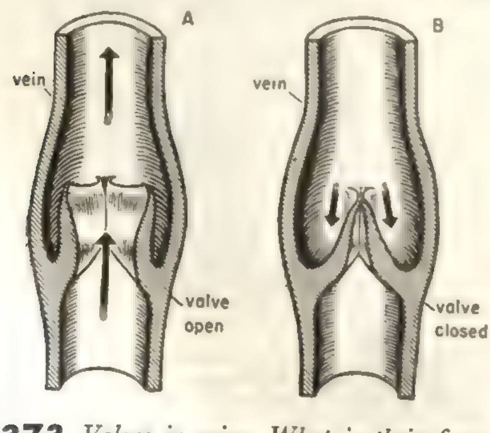
372
You see here the six main pressure points by which arterial bleeding can be controlled. To stop bleeding, press on point nearest the wound between the wound and the heart. (From "First Aid," courtesy Metropolitan Life Insurance Co.)

the heart and the point of injury. A pressure point is a place where the artery is found near the surface of the body. Here pressure can be exerted against a bone. Examine Fig. 372 and locate on your own body these pressure points. Of course, for any major cuts the doctor should be called immediately.

Veins have less muscle and less elastic tissue than arteries. Their walls are, therefore, thinner than those of arteries. The blood merely flows from a cut vein instead of spurting.

Since veins carry blood back to the heart against the force of gravity, you would expect them to have structures which would help in this job. If you examine a vein, you will find valves which help in moving the blood back to the heart by stopping the backflow (Fig. 373).

Think of the blood moving against gravity up the veins in your legs and your body to the heart. With each contraction of the ventricle of the heart, the blood moves along in every vein in your body. With each relaxation, the blood falls back in each vein, only to be halted by valves (Fig. 373). One place to see a number of these valves is on the inner surface of your arm. If you let your arm hang down and keep



373 *Valves in veins. What is their function?*

clenching your fist, you may be able to see small bumps along the veins. These are the places where the valves are located.

RED, WHITE, AND BLUE BLOOD

Have you ever heard of "red-blooded people" and "blue bloods"? These expressions do not square with the scientific facts.

Every human being's blood, yours and your neighbor's, is bright red in the arteries and dark red in the veins. Blood is bright red in the arteries because these blood vessels carry red blood corpuscles to which oxygen has been added in the lungs. This is called *oxygenated* (ŏk′sĭ jĕn āt′ĕd) blood. Blood returning from the body through the veins has given up about 4 to 6 per cent of its oxygen and is a dark red blood—*deoxygenated* blood. It is only because we see our veins through the skin that they appear blue.

But some people also use the term "white blood." Have you ever had a skin blister from the rubbing of a tennis racket or baseball bat? The blister is filled with lymph, which is a colorless or whitish fluid. This fluid comes from the plasma of the blood, which filters through the walls of the capillaries as it is needed. As it filters through, the blood cells and certain other elements of the blood are left behind in the capillaries.

Some portion of every living cell of your body is in contact with lymph. Food substances and oxygen diffuse out of the capillaries into the lymph. From the lymph they diffuse into your cells. As the cells use the food and oxygen, waste products are formed. The wastes diffuse out of the cells into the lymph and reach the capillaries. Thus lymph is a sort of "middleman" between your cells and capillaries.

The blood which is brightest red will

be found in one of the veins. Where is the blood oxygenated? In the lungs. What kind of blood vessel brings this bright red oxygenated blood to the heart? This is a vein, of course, since veins carry blood to the heart. This is the one exception to the rule that all veins carry deoxygenated blood.

THE LIFE STREAM

Look at the tip of your finger. Right now oxygen and nutrients are leaving the capillaries in that tip. These substances diffuse into the lymph surrounding the cells of the fingertip. As a matter of fact, every cell in your body is now receiving these materials.

At the same time that the cells are taking oxygen and food nutrients, they are giving off wastes in the form of carbon dioxide, water, and nitrogen compounds (Fig. 374). These last are sometimes called *nitrogenous* (nī trŏj′ĕ-nŭs) wastes. These wastes leave the cells of the body and diffuse across the lymph into the capillaries. From the capillaries most of the wastes will eventually get into the blood vessels leading to the kidneys. In the kidneys the nitrogenous wastes will be removed.

Arterial blood vessels bring oxygen and nutrients to the capillaries. *Venous* (vē′nŭs) blood vessels take wastes away. Your blood protects your health in these main ways:

1. It carries food and oxygen to every cell of your body.
2. It removes wastes from your cells.
3. It has white blood cells, antibodies, and clotting substances which protect you against disease.
4. It carries special substances such as hormones which aid your growth and other body functions.

Truly your blood is a life stream; without its proper function life cannot go on.

BLOOD WILL TELL

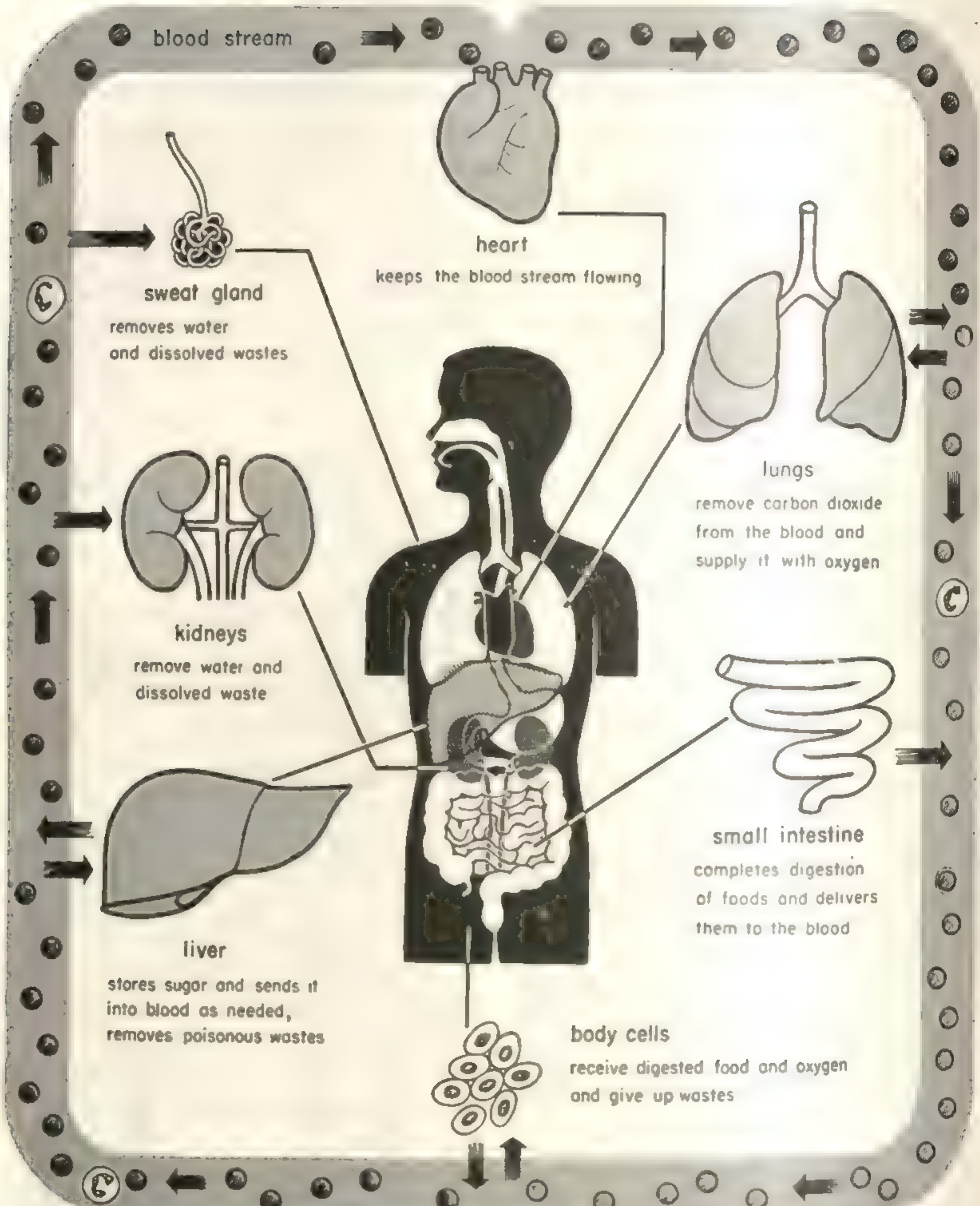
Now you have some idea of what the doctor learns from his examination by stethoscope. He learns whether your heart is efficient in pumping nutrients and oxygen to every part of your body. He hears the valves of the heart snap into place as the ventricles contract.

He can determine by other methods whether your blood system is efficient. His microscope tells him whether your white and red blood cells are sufficiently numerous. By chemical analysis he learns a good deal about your blood plasma, especially about its all-important food nutrients. Yes, blood will tell. It tells the expert what he needs to know about the condition of your health. An efficient heart, efficient blood vessels, and good blood in them, mean that all parts of your body are being supplied with the substances they need for good health.

CARING FOR YOUR HEART

Place your hand over your heart. Feel the beat of this remarkable organ. Today, your heart beats about 70 times a minute, 4,200 times an hour, a total of about 58,800 times in 24 hours. Thus it drives the substances you need around your body. It is the center of a system of circulation which is a life line to every cell. The efficiency of your circulatory system is a thing to marvel at.

Yet medical science has found that heart disease and other diseases of the circulatory system are the greatest killers of our time. In one sense, this means that we do not really understand all we need to know about our hard-working circulatory system. But many of the deaths due to heart diseases could be prevented if everyone had an annual physical examination. During the examination, any defect in the



374 *Circulation of the blood, the life stream. It carries food and oxygen to the cells and body organs and takes away waste products. (Adapted from drawing by Marion A. Cox for "Your Health and Safety: Revised," by Clemensen and LaPorte, courtesy Harcourt, Brace and Company)*

heart may be discovered and treated.

In 1948, heart disease killed almost twice as many people over 40 years of age as did cancer. Doctors are convinced that a great number of these deaths were unnecessary. Many believe that the basis for heart disease is laid early; that is, the poor health practices

which eventually injure the heart begin while people are young.

It is useless to give you the symptoms of heart disease, for only an experienced doctor can recognize the evidence. But we repeat—and this cannot be repeated too often—a medical examination every year will help detect many heart diseases so that they can be treated in time. Have you had yours?

It is clear that as scientists learn more about the circulatory system we may expect longer and happier lives. In your lifetime, the scientific discoveries which will yield this information may be made. Watch for them. You or one of your schoolmates, or at least one of your generation, may be the medical researcher who will help make the discoveries which are needed.

GOING FURTHER

1 *Seeing circulation.*

1. Examine slides of Daphnia (p. 548). Catch a few of the animals found in pond water by drawing them up into a medicine dropper. Place them on a slide and cover them gently with a cover slip. Observe the heartbeat.

2. Examine circulation in the tail of the goldfish.

3. Place a frog in a jar in which a piece of cotton soaked in ether has been placed. When the frog is completely relaxed, place the frog on a piece of cardboard. Cut a round hole (the size of a quarter) in one end of the cardboard. Stretch the web of the foot over this hole and examine it by means of a microscope. Notice the small blood vessels. Can you see the blood cells circulating in the smallest vessels?

2 *Dissecting a heart.* Dissect a sheep or beef heart. Use the descriptions and diagrams on page 548 to help you.

3 *Circulation and exercise.*

1. Take your pulse. Now trot for three minutes. Take your pulse again. Has it gained? How does this increase in pulse beat help your body act more efficiently during exercise?

2. How soon does your pulse become normal after exercise?

3. Try this experiment again after different forms of exercise—deep knee bending, jumping rope, etc.

4 *Words are ideas.* Can you use these words in a sentence which will give their meaning? Use the glossary.

blood	lacteal	antibodies
plasma	red blood cell	hormones
auricle	white blood cell	hemoglobin
ventricle	oxygenated blood	intestine
heart	deoxygenated blood	villus
artery	enzyme	membrane
vein	gastric juice	digestion
capillary	pancreatic juice	

5 *Put on your thinking cap.*

Your heart pumps about 10 pounds of blood per minute into your arteries. How many pounds is this per hour? Per day? How is this evidence that the blood circulates?

6 *Test yourself.* In your notebook, complete the following statements with a word or phrase which will make them true. Do not mark this book.

1. An ...... found in saliva breaks down starch to sugar.

2. The ...... is a gland which produces some of the intestine's digestive juices.

3. In digestion, insoluble foods become ....

4. Digested foods are absorbed by microscopic fingerlike structures called ....

5. The blood carries food and ...... to the cells of the body.

6. ...... carry blood toward the heart.

7. ...... carry oxygenated blood.

8. The blood circulates through the body about two times each ....

9. ...... cells of the blood are primarily for combating germs.

10. The ...... are the smallest blood vessels.

CHAPTER 31

YOUR CELLS IN ACTION

Have you ever watched a champion basketball team or a good symphony orchestra in action? How smoothly the players work together! What teamwork! Each player knows what to do at exactly the right time.

Your body is a team—a team of cells which are the body's building blocks. Both before birth and afterward they give you a smoothly functioning body.

In a healthy body, each cell does its job constantly throughout its life. However, when certain cells stop doing their job, because of an injury or a disease, your body loses its efficiency. Illness is the result. Then the doctor is called to do his best to return these cells to their work.

THE ORGANIZATION OF THE BODY'S CELLS

Why do scientists "waste" time studying cells when they could study important things like cancer and tuberculosis? This question has been asked time and time again. Yes, why study cells at all? What is their importance to your health?

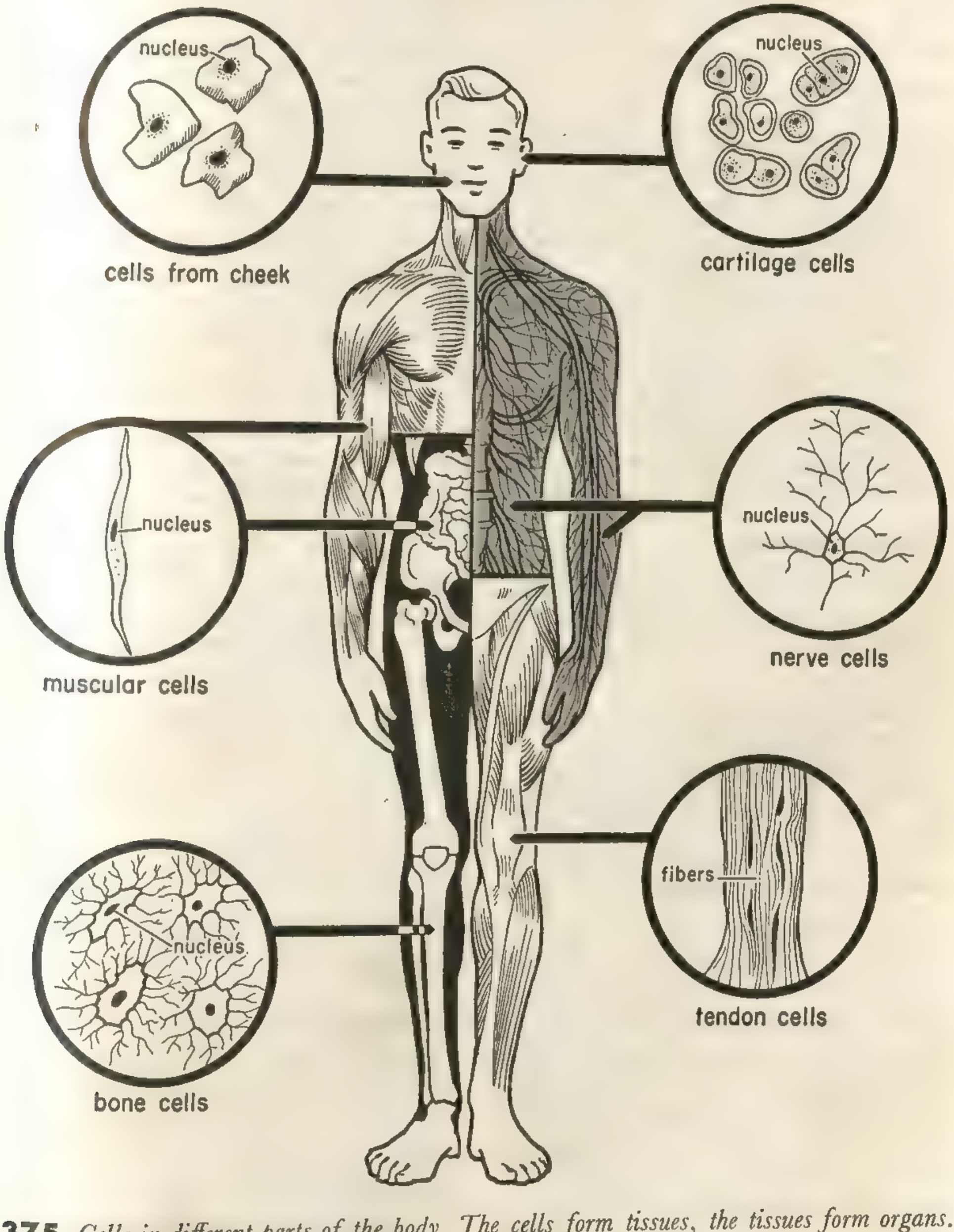
CELLS EVERYWHERE

Let us examine some of the cells in your body.

You will need a microscope, some glass slides, water, a medicine dropper, and some stains such as 1 per cent iodine in alcohol. Now take a toothpick and gently scrape the inside of your cheek. Put the scrapings in a drop of water and add a drop of iodine. The slide goes under the microscope and what you see resembles Fig. 375. Here and there are groups of small bodies, the cheek cells. Each cell has its *nucleus* surrounded by *cytoplasm* (that part of the *protoplasm* outside the nucleus). The cytoplasm in turn is surrounded by a *cell membrane.* Protoplasm, as you remember, consists of the entire contents of the cell: its nucleus, cytoplasm, and cell membrane.

Scrape again. No matter where you scrape your cheek you get the same kind of cells. If you could see them as they cover the inside of your cheek, you would see a flat sheet of cells all similar in shape and size. Their function is protection. Any group of similar cells specialized for performing one function is called a *tissue* (tĭsh'ū).

Other cells of the body are harder to examine than are protective cells of the cheek. However, we can examine cells of other animals. In the frog, for instance, we find cells which look like those in Fig. 375. These are muscle cells; they are long and slender. Each one can shorten and lengthen as required when the whole muscle contracts in doing work or relaxes at rest. Your muscle cells act the same way as those of other animals.



375 *Cells in different parts of the body. The cells form tissues, the tissues form organs. The entire body is made up of cells and their products.*

The cells of the nerve tissue are long fiberlike cells (Fig. 375). Nerve tissue keeps the different parts of the body in touch with the brain, which is itself composed mainly of nerve tissue. Finally, there are other cells which form bone, cartilage, and tendons (Fig. 375).

Thus in your body, you will find cells grouped in tissues with the following functions:

1. Protection—the cells which cover the inner and outer surface of the body, such as the cells of your cheek and skin. The cells which line your intestines and lungs are grouped with the other protective cells of the body.
2. Contraction and expansion—muscle cells.
3. Communication—nerve cells.
4. Support—the cells which make cartilage, bone, and tendon.

Some biologists also consider blood with its red and white cells a tissue.

TISSUES INTO ORGANS

Just as cells are grouped into tissues so tissues are grouped into organs (Fig. 375). Each organ has its special function. For instance, your eyes and ears are sense organs. Your lungs are organs for breathing. Your stomach is an organ for digestion. Each organ has not just one but many different kinds of tissue cells.

ORGANS INTO ORGAN SYSTEMS

Our bodies, you can see, are well organized. The cell is the building block. It is the smallest living unit into which we can divide our bodies. These cells in turn make up tissues. Tissues make up organs. Several organs may work together in a system (like the digestive system). Organ systems make up the body. It is the organism as a whole in which the various parts work in harmony. An organism is well organized.

BUILDING CELLS

It is the cell, then, which is the building block of the body. You are no healthier than your cells. In another chapter (Chap. 30), you learned that blood brought digested food and oxygen to every cell in your body. The food nutrients then diffused through the membranes of the cell. What happens to these nutrients?

You can get part of the answer by weighing yourself. What is it that you are weighing? Yourself? True. But you are also weighing human protoplasm (prō′tō plăz′m) and its products. The cell consists of protoplasm, the living substance of which all living things are made. The process by which cells turn digested food into protoplasm is called *assimilation.* Your cells are assimilating now and will do so every second of your life. Good growth means good assimilation.

Even before you were born, cells assimilated the digested food and added to your weight. Examine Table XII and see how much more you will weigh as you grow older. Remember that these weight charts are based on the average weights of many boys and girls. Your normal weight may be below or above the average. If it is too much (more than 10 per cent) above or below for your age and height, ask the advice of your doctor. Probably nothing is wrong but it is safer to check up.

PRODUCTS OF CELLS

Growth is a result of assimilation. But cells not only produce more protoplasm; they also produce nonliving materials such as bone or cartilage. When cells produce useful material for the body other than protoplasm, they are said to secrete these materials.

Table XII. AVERAGE WEIGHTS FOR BOYS AND GIRLS

Height	Age 13		Age 14		Age 15		Age 16		Age 17		Age 18		Age 19		Height
Inches	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Inches
52	64														52
53	68	71													53
54	71	73	72												54
55	74	77	74	78											55
56	78	81	78	83	80										56
57	82	84	83	88	83	92									57
58	85	88	86	93	87	96		101							58
59	89	92	90	96	90	100	90	103		104					59
60	93	97	94	101	95	105	96	108		109		111		113	60
61	97	101	99	105	100	108	103	112	106	113		116		118	61
62	102	106	103	109	104	113	107	115	111	117	116	118		120	62
63	107	110	108	112	110	116	113	117	118	119	123	120	127	122	63
64	111	115	113	117	115	119	117	120	121	122	126	123	130	125	64
65	117	120	118	121	120	122	122	123	127	125	131	126	134	128	65
66	119	124	122	124	125	125	128	128	132	129	136	130	139	132	66
67	124	128	128	130	130	131	134	133	136	133	139	135	142	137	67
68		131	134	133	134	135	137	136	141	138	143	138	147	141	68
69			137	135	139	137	143	138	146	140	149	142	152	146	69
70			143	136	144	138	145	140	148	142	151	144	155	150	70
71			148	138	150	140	151	142	152	144	154	154	159	158	71
72					153		155		156		158		163		72
73					157		160		162		164		167		73
74					160		164		168		170		171		74

(Adapted from tables prepared by B. T. Baldwin, Ph.D., and T. D. Wood, M.D. Courtesy of American Child Health Association and American Public Health Association.)

Secrete in this sense means deposit or build up, not "hide away."

Certain cells in your body secrete the materials which form bone and teeth. Bone is hard and made for support. Now flip your ear with your finger. The ear can bend yet keep its position because of the cartilage in it. Cartilage is flexible enough to bend but rigid enough to support other tissue and give shape to it. The baby's skeleton is at first made of cartilage most of which is later replaced by bone. Next time you have meat for dinner ask your mother to save the flexible gristle. Gristle is fairly hard cartilage. Such materials as calcium and phosphorus are used by body cells in producing bone, cartilage, and teeth.

Nails and hair are formed from cells. No one really knows how long nails can grow, but the cells at the base of your nails are constantly forming more nail. And you go regularly to the barber to cut the hair constantly being formed by hair cells.

REPLACING LOST CELLS

Does your skin peel when you sunburn? Have you ever had a cut or a burn? New skin always forms. New cells are formed which take the place of those destroyed. Cells not only secrete the materials which form bone and cartilage, not only do they form hair and nails, but they produce other cells like themselves by cell division. In addition, the cells on the surface of the skin are always wearing away. You probably rubbed some away when you washed this morning. These cells were replaced before they were rubbed away.

One-third of your red blood cells will be destroyed within the next 20

days as they are in every human being. The cells must be replaced; otherwise not enough oxygen will be brought to your body cells. Cells in every part of your body wear out and are replaced by new cells. Scientists have recently put radioactive elements to work in studying body cells. From this kind of investigation it has been estimated that the body replaces most of its active cells in a period of two and a half years.

WHERE THE LIFE FIRES BURN

If you are to carry on your daily activities, your body must be furnished with energy. Can we measure this energy in any way? Perhaps we can compare a living thing which is growing actively with one which is not. It would be impossible to compare two animals of the same age, one of which is not growing or assimilating, with one which is. As soon as assimilation in animals stops, they die. But plants are different. Plants can lie dormant, that is, stop assimilating, while they are in the seed stage. However, in many basic activities, plant protoplasm and animal protoplasm are somewhat the same—sufficiently similar to enable us to compare their outputs of energy.

MEASURING ENERGY OUTPUT

Let us, therefore, take some dried beans and divide them into equal parts by weight. The dried beans are alive. Proof? Plant a few and a living plant is produced. The dried beans are just in a resting stage.

Water is needed to make the cells in the seed active, to make them grow. Now we shall soak one half of our seeds overnight and keep the other half dry and inactive. How shall we measure the energy output, if there is any? We can measure the heat energy produced by placing the soaked seeds in one thermos bottle, the dry ones in another. Then we fit each thermos bottle with a one-hole rubber stopper and insert a thermometer in each stopper.

WATCH THE TEMPERATURE

The bottle containing the soaked seeds shows a higher temperature. Why? Heat energy is being produced by the soaked seeds. However, no heat energy is produced by the dry seeds. After a few days young plants will sprout from the soaked seeds. The dry seeds do not sprout. Growth and assimilation are accompanied, it has now been demonstrated, by the production of energy.

HOW DO CELLS PRODUCE ENERGY?

One way of producing energy is to burn coal. The carbon (of which the coal is mainly composed) combines with oxygen to produce carbon dioxide and heat energy. Something similar happens in the body, except that it is the food and not coal which is burned. There is no flame produced, but energy, such as heat energy and mechanical energy, results. Slow burning of food, which takes place without the production of a flame, is called slow *oxidation* (ŏk′sĭ dā′shŭn). As in the fast burning of carbon, oxygen combines with the food. In rusting, which is even slower than the oxidation of food, oxygen combines with iron.

INVESTIGATING OXIDATION

Let us burn a substance like a small amount of fat in a jar. We find that oxygen is necessary because if we cover the jar, the flame goes out. When we

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This student is breathing air in from one flask and breathing it out through the other. The limewater in the flasks turns milky in the presence of carbon dioxide. Through which flask is she exhaling? This demonstration can be used to show that the lungs exhale more carbon dioxide than they inhale. (*David B. Eisendrath*)

add limewater to the air in which the food has burned, we find the limewater turns milky. Therefore, we know that carbon dioxide has been given off. On the side of the jar in which we burned the butter fat, we find droplets of water.

All this is easy to explain. Fats, as well as carbohydrates, you remember, are made up of carbon, hydrogen, and oxygen. The carbon combines with oxygen to form carbon dioxide (CO_2). The hydrogen combines with oxygen to form water (H_2O).

OXIDATION IN YOUR BODY

Unquestionably you are oxidizing now. There are three pieces of evidence for this statement.

First, put a thermometer in your mouth. Since it reads 98.6° Fahrenheit or 37° centigrade, you are producing heat. Doctors know that your cells are not functioning well when you produce a slightly lower or higher temperature.

Second, blow your breath into limewater by means of a straw. Since the limewater turns milky, you are producing CO_2.

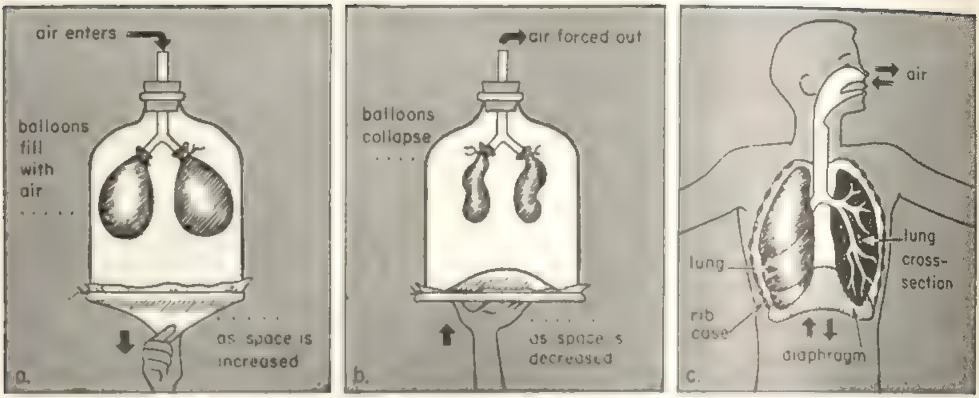
Third, go over to a mirror and let the breath from your nostrils touch it. You are exhaling water.

But perhaps these tests do not really prove that you are oxidizing. How do you know that you weren't taking in as much carbon dioxide or water as you were breathing out?

WHAT DO WE INHALE AND EXHALE?

If somehow we could test the air that comes into the body and the air that leaves it, we would have definite proof that passage through the body changes it. When air enters the body, we say we inhale air. When air leaves the body, we say we exhale air. The simple apparatus in Fig. 376 enables you to inhale air through the water of one bottle and exhale it through the water in the other bottle.

Now put some limewater in both bottles of your apparatus; then put the breathing tube (Fig. 376) in your mouth; then inhale through one bottle and exhale through the other. The limewater in the bottle through which you exhale should turn milky because of the increased amount of



377 *A demonstration of how we breathe. Compare the chest cavity* (c) *with demonstrations* (a) *and* (b). *It is the diaphragm and chest muscles rather than the lungs which move the air in and out.*

carbon dioxide in exhaled air. The other bottle should remain clear by comparison. Why? The air which is inhaled contains a very small amount of carbon dioxide. Exhaled air contains almost 4 per cent CO_2 because some of the oxygen has been changed into carbon dioxide.

You can use the same apparatus to prove that you exhale water. Dry both bottles. Embed them in ice, or dry ice. Now breathe in and out for a few minutes. The bottle through which you exhale will contain some water condensed from the water vapor in your breath. Indeed, it has been found that we lose about one-third of a quart of water a day from our lungs.

If we were to write a rough equation for oxidation of food, we might put it this way and get a good summary of what is involved in oxidation:

$$O_2 + \text{food} \rightarrow CO_2 + H_2O + \text{energy}$$

Or as the chemist writes it when sugar is being oxidized:

$$6O_2 + C_6H_{12}O_6 \rightarrow 6CO_2 + 6H_2O + \text{energy}$$

Scientists have found that glucose or grape sugar is a carbohydrate commonly oxidized in the body. As you remember, glucose is the end product of digestion of carbohydrates. The energy produced in the oxidation is used during growth and for maintaining your body temperature. It also supplies the energy for your work and play. Remember, however, that glucose is used not only for oxidation. Some of the glucose is used to help build the body proteins. Some of the glucose is also stored in the liver and muscles as animal starch, called glycogen (glī′kō jĕn), to be used in time of emergency. An excess of glucose is changed into and stored as fat. Glucose, you can see, is a basic substance used in the body.

SUPPLYING OXYGEN TO THE BODY

You know that the digested food is brought to the cells by the blood and lymph. You also know that oxygen must reach each cell. How does oxygen get into the blood?

First, air enters through your nostrils and is warmed and moistened as it goes through the nasal passages. At the back of the mouth it enters the windpipe (Fig. 377). Then about a pint of air enters your lungs at one breath.

HOW AIR GETS INTO THE LUNGS

Most people think that the air is pulled into the body by the lungs. Not at all. Pull in your diaphragm as far as you can. Now try to breathe. It is difficult because you are not permitting your diaphragm to relax and expand. Your diaphragm is a flat sheet of muscle which bounds the lower part of your chest cavity (Fig. 377). If you were to take a bell jar and tie a sheet of rubber at the wide opening at its base, the sheet of rubber might represent the diaphragm and the bell jar your chest cavity. If you also attach two balloons to a Y-tube as shown in Fig. 377 you will have a kind of model of the chest cavity.

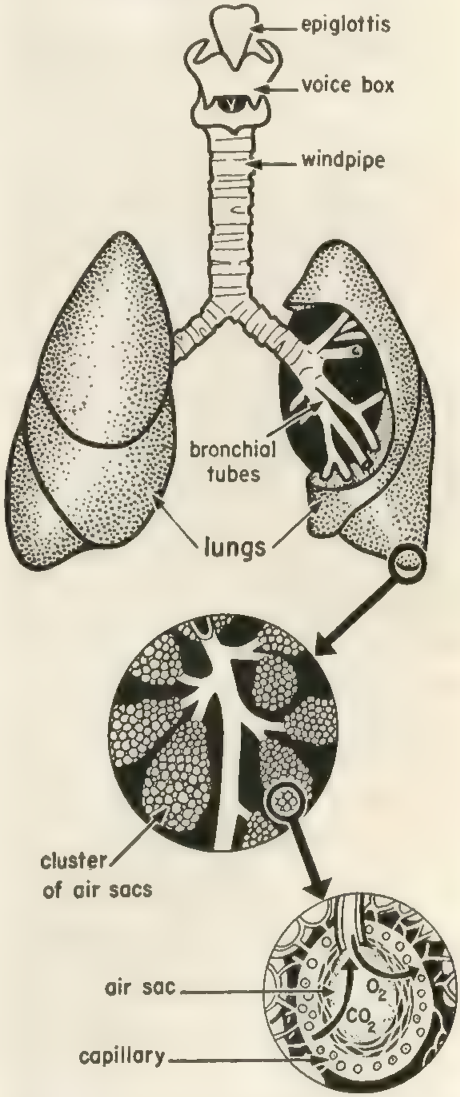
Now if you pull down the rubber sheet, you will increase the space in the bell jar. The air inside the jar will then be at a lower pressure than will the air outside. The greater air pressure outside will cause air to enter the balloons. They will expand. If you push the rubber diaphragm up, the reverse happens. The air pressure inside is increased. The balloons collapse.

If we could make the bell jar expand, however, we would be nearer to what happens in your chest cavity. When we inhale, our ribs are pushed out as well as the diaphragm. As they expand, thus expanding the chest cavity and reducing the air pressure inside, air rushes into the lungs. In exhaling, the chest cavity becomes smaller and the air pressure in the cavity is increased. This pressure on the lungs causes them to collapse slightly and to expel some of the air. Hence, it is the diaphragm and the chest muscles that "pull" air into the body and expel it.

YOUR LUNGS

A pair of beef lungs would give you a very good idea of your own (Fig. 378).

378 (Top) *Diagram of the lungs and windpipe.* (Center) *An enlargement of the microscopic air sacs of which the lungs are made.* (Bottom) *A still greater enlargement showing one air sac.* (*Adapted from drawing by Marion A. Cox for "Exploring Biology: Third Edition," by Ella Thea Smith, courtesy Harcourt, Brace and Company*)



First, you would notice that lung tissue is spongy. Second, if you cut into the

lung you would notice that there are fine air tubes throughout (Fig. 378). These tubes can be traced back to the windpipe. The windpipe is kept from collapsing by rings of cartilage (Fig. 378). The windpipe divides into two tubes called *bronchi* (brŏng'kī), which in turn branch out through the lungs like the roots of a tree. Finally, each of the smallest air tubes reaches an air sac (Fig. 378).

The lungs contain millions of air sacs. If the air sacs of one lung were spread out, they would form a membrane which could cover the floor of a room 50 feet long by 22 feet wide. You will get a good idea of a group of air sacs if you imagine a froth of small soap bubbles. Each bubble represents an air sac. The walls of each air sac are surrounded by a network of capillaries.

You can imagine what happens. Twenty per cent of the air entering these air sacs is oxygen. The oxygen diffuses rapidly through the thin cells lining the air sacs into the capillaries. At the same time carbon dioxide in the capillaries diffuses into the air sac. Thus oxygen goes into the blood and carbon dioxide goes out of the blood into the air sacs.

FROM THE LUNGS TO THE BODY CELLS

We know water can contain only about 3 per cent of dissolved oxygen by volume. Yet our blood, composed mainly of water, dissolves about 20 per cent by volume. As you know, the red blood corpuscles contain hemoglobin, which combines with the oxygen. This hemoglobin gives up its oxygen when it reaches the cells of the body.

Thus, as the arterial blood stream goes to the cells, it carries oxygen which the cells use in burning up or oxidizing nutrients. Oxidation furnishes energy for all your body functions: growth, repair, and activities like moving muscles of the limbs, breathing, relaying impulses through nerves; in short, all the activities of your body. In this oxidation, carbon dioxide and water are produced and diffused through the cell walls into the blood. The blood coming back to the lungs in the veins carries carbon dioxide and water as wastes of oxidation, as well as some of the oxygen which hasn't been used up.

CELLS WHICH STORE ENERGY

You know that not all the food you eat is used immediately in producing energy for growth, assimilation, and the general activities of the body. What happens to the proteins, carbohydrates, and fats which are not immediately used?

EXCESS FOOD IS STORED

Do you remember any stories of sailors adrift in lifeboats without food for weeks or sometimes even more than a month? They lived on their stored fats and carbohydrates. Carbohydrates which are not oxidized are stored in the liver and muscle cells as glycogen, a type of animal carbohydrate. Glycogen can be broken down into glucose. Indeed, during fasting, the glycogen is broken down into glucose sugar and passes into the blood. It has been found that when a person takes part in some event in which a good deal of energy is needed, the body draws on the glycogen and breaks it down to sugar. Thus more sugar is ready for oxidation.

Fat, however, is stored in fat cells. It can be broken down and used for energy but not so quickly as glycogen. Animals that hibernate, like bears,

ground hogs, frogs, or snakes slowly use the fat stored in their bodies as a source of energy during their long season of sleep and rest.

DANGERS IN STORING EXCESS FOOD

In human beings, too much stored fat may be harmful. Especially is this true of the heart, whose muscles may be overburdened if fat is stored in cells around them. In addition, it is more work for the heart to pump blood through the fat stored under the skin and around the intestines. People who allow excess fat to build up in their bodies place a strain on their hearts. It is wise, therefore, to try to lose excess fat, but only under a doctor's advice. There are many reasons why people are overweight. A doctor can best investigate the cause and treat it. Don't rely on advertisements or neighbors, or your own judgment.

THE WORK OF THE CELLS

Cells are important for many reasons:

Cells make new protoplasm; they assimilate.

Cells replace worn-out and dead cells; they produce more cells.

Cells produce energy from food; oxidation goes on in the cells.

Cells store excess food; they store fat and glycogen.

Cell activities are the basis of all the activities in the body. Your cells never rest.

Studying the cell means going to the very basis of health and of life.

GIVING CELLS A GOOD ENVIRONMENT

When you say you are well, you actually mean that the cells of your body are functioning smoothly. You can see, therefore, that keeping healthy means keeping all your cells healthy. The chemical environment of all the cells is regulated so that two processes work continually: (1) the substances the cells need must be constantly supplied by the blood and lymph; (2) just as important, the chemical wastes which the cells give off must be rapidly removed. Unless removed, wastes quickly start to poison the cells, upset their chemical functioning, and spoil the smooth operation of the body.

REMOVING THE WASTES OF CELL ACTIVITY

As you recall, not all the food you eat is digested. That which is not digested leaves the body as solid waste through the large intestine and rectum. This part of the food has never reached the cells. You know, too, that digested food reaches the blood stream and eventually every cell of the body. Some food, too, is stored in fat cells.

The blood stream not only transports food, but also removes the wastes of cell activity. Some of the wastes are carbon dioxide and water (resulting from oxidation). The water can be used again by the body. But cells produce other wastes, especially when proteins are oxidized. These wastes contain nitrogen and are called nitrogenous wastes. One of the most important of them is a substance called *urea* (ū rē′ȧ).

We know that carbon dioxide and some water are removed through the lungs. How are other wastes removed?

REMOVING WASTES THROUGH THE SKIN

If you examine some skin which has been prepared for study under the microscope, you will be able to see how the skin is adapted for removing wastes. First, among other structures you will notice that the skin has sweat glands (Fig. 379). These sweat glands

take some of the salts, urea, and water from the blood and excrete them through the surface of the skin. During violent exercise the sweat flows freely. You can also see that bathing helps to remove the salts and urea from the skin as well as substances which are the cause of body odors.

REMOVING WASTES THROUGH THE KIDNEYS

The lungs and skin, as you have learned, remove some of the wastes of cell activity. However, wastes are also removed through the two kidneys. Imagine a kidney bean about four inches long and you have an idea of the shape and size of the kidney. A large artery enters and a vein leaves each kidney just where it is indented (Fig. 380). The blood in the artery brings the nitrogenous and other wastes to the kidney. The blood in the vein leaving the kidney is practically free of them. In the kidney, the wastes are filtered out through the membranes of thousands of tiny tubes. But the useful substances like glucose are left in the blood. How the cells of the kidney do this is not yet fully known. Here is another unsolved problem for some young scientist to tackle.

In any event, the wastes are extracted from the blood and dissolved in water in the kidney. Drop by drop they pass from the kidney into the bladder. They leave the body eventually through a tube which leads to the outside (Fig. 380).

379 *A diagram of the skin. How does sweat reach the surface of the skin?*

WORKING TOGETHER

Your body, then, is composed of a team of cells each one doing its job at the right time. All your cells do their jobs from the moment life begins. They do not need coaching. Scientists say that cells grouped into tissues, and tissues into organs inherit their functions. They do their jobs, therefore, from birth.

Your living cells function throughout your life, when you are asleep as well as when you are awake. They never stop working. As old cells wear out, new cells are made which replace them.

Each type of cell is a specialist. Red blood cells carry oxygen. Muscle cells are responsible for the movements of your body. Skin cells protect. The cells in your digestive tract produce enzymes. Some cells in your eye detect light waves and some in your ear detect sound waves.

Cells act together, each one dependent on the other. In acting together

the cells enable your body to function. Healthy living keeps cells in a healthy condition.

GOING FURTHER

1 *Cells of the frog.* Place a frog in a jar containing one inch of water for 48 hours. In that time, it will have thrown off a sheet of cells which covers the skin. Place them on a slide and examine them under the microscope. Stain them with a drop of 1 per cent iodine in alcohol. Draw them.

2 *Testing your lung capacity.* How much air do you breathe in? Get a gallon bottle and fill it with water. Cork it. Now place it mouth down in a large pan containing water. Remove the cork and insert a long piece of rubber tubing.

Take a deep breath. Now breathe out the air in your lungs through the rubber tubing. How does this tell you your lung capacity? Compare your lung capacity with that of your friends.

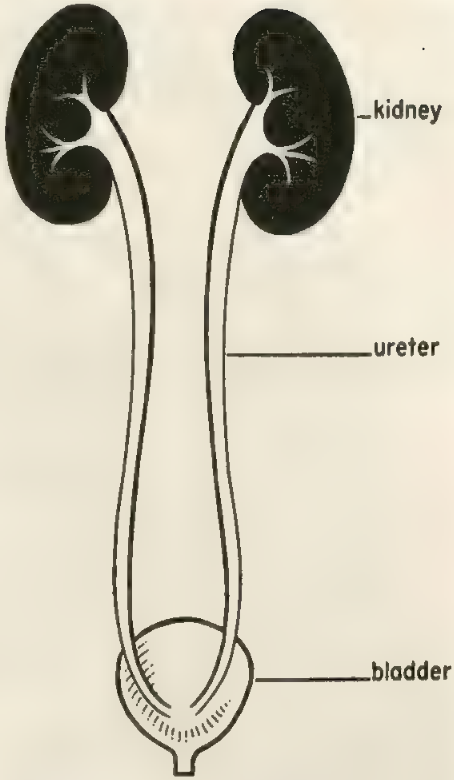
3 *Words are ideas.* Can you use these words in a sentence which will give their meaning? Use the glossary.

cell	glycogen	kidneys
cytoplasm	oxidation	cell specialist
cell membrane	excretion	tissue
nucleus	lungs	organ
diaphragm	sweat glands	bronchi
	air sacs	

4 *Put on your thinking cap.*

1. Two scientists discovered a very important function of glands in this way: They fed one dog. Then after he swallowed his food they took some of his blood and injected it into the vein of a second dog who had not been fed. The second dog began to produce gastric juice. What do you conclude from this experiment?

2. In 1839 two scientists, Schleiden and Schwann, made the statement that the cell is the basic unit upon which the body is built. This was called the Cell Theory. On the basis of your knowledge of cells, defend the idea that this is no longer a theory but a fact.



380 *A diagram of the kidneys and their tubes. Water containing dissolved wastes leaves the kidneys, enters the ureters and is stored in the bladder until it leaves the body.*

5 *Test yourself.* In your notebook, complete the following sentences with an accurate word or phrase. Do not mark this book.

1. The living material in the cells of the body is called ....

2. The elements most important for the building of bones are calcium and ....

3. Exhaled air is different from inhaled air in that exhaled air contains less ....

4. Three important waste products resulting from oxidation in the cells are ......, ..., and ....

5. Some useful materials for the body produced by cells are ....

6. The organs that are chiefly concerned with excretion are the lungs and ....

7. A great deal of glycogen is stored in the ....

8. The blood cells which are regularly destroyed are the ....

9. A group of cells performing the same function is organized into ....

10. A group of tissues performing a special function is called an ....

CHAPTER 32

YOUR BODY vs. UNSEEN KILLERS

Have you had your annual medical examination? If you have, you probably remember the fine, safe feeling that only a medical examination passed with flying colors can bring. You also resolved, perhaps, to eat the proper food; to get enough rest and sleep, exercise, fresh air and sunlight; to keep cheerful; and to work to your capacity.

Is this enough to keep your body in the best of health? One must be able to ward off diseases caused by germs. But how can you ward off diseases if germs are everywhere—in the air, on your clothing, on your body, yes, even on your lips and in your mouth?

STUDYING THE UNSEEN

If we can find out what kinds of germs there are, perhaps then we shall see how they may be destroyed. Let us begin by doing an experiment to determine where germs can be found.

"SEEING" THE UNSEEN

Take several Petri dishes filled with nutrient gelatin, on which bacteria can grow (Fig. 381). Sterilize the dishes in a steam pressure chamber so that nothing could possibly remain alive in them. After the dishes have been sterilized and cooled, use three of them to test for the presence of germs. For the first, take a wire loop which has been heated red-hot in a Bunsen flame. This will have killed anything alive on the loop. As soon as it cools, insert the loop in a drop of water from the faucet and brush the surface of the nutrient gelatin, making a figure **N** or **8** on the gelatin. In a second dish press your fingers gently on the gelatin. Place a hair from your head on the third.

Leave a few sterilized Petri dishes untouched. Why? They will be the controls which must be present with each experiment. Nothing alive should be found in them.

The Petri dishes are placed in a warm, dark place. An incubator, which is only an electrically heated oven, will do very well. It should be kept at body temperature—37° centigrade or 98.6° Fahrenheit. Leave the dishes there for two days. If you do not have an incubator, place the dishes in a dark, warm place in your classroom.

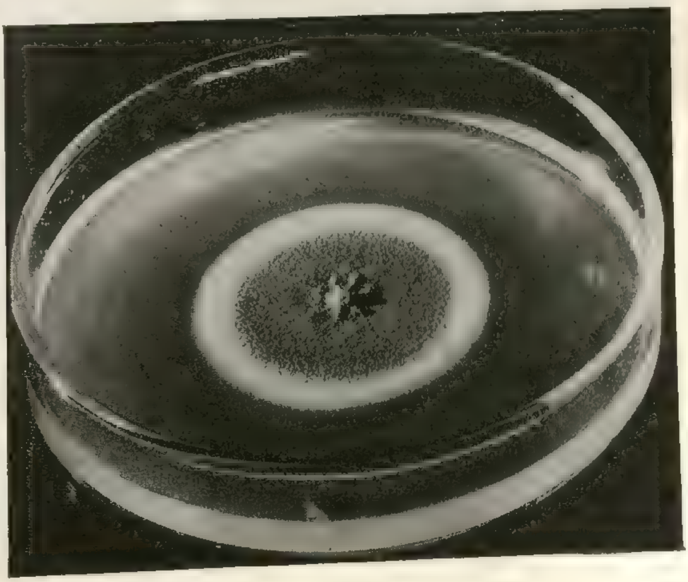
When you take the Petri dishes out of the incubator, you probably will discover that there were germs in the water, on your fingers, and on your hair—there will be whitish or grayish blotches which certainly were not there two days ago. The controls are clear; there are no growths on them.

KINDS OF BACTERIA

To examine the Petri dishes you will need the wire loop, a microscope, some slides, and a stain like methylene blue. Let us take some material from the blotches in the dishes and examine it under the microscope. Take a bit with the wire loop and smear it on a slide. Pass the slide slowly through a low flame four or five times and then stain the slide with a dye like methylene blue. If you make a careful examination under the highest power of a microscope, you may find three types of organisms. Some are rod-shaped, called *bacilli* (bȧ sĭl'ī, Fig. 382 top). Some are spherical, called *cocci* (kŏk'sī, Fig. 382 center). Some are spiral-shaped or bent rods; these are *spirilla* (spī rĭl'ȧ, Fig. 382 bottom).

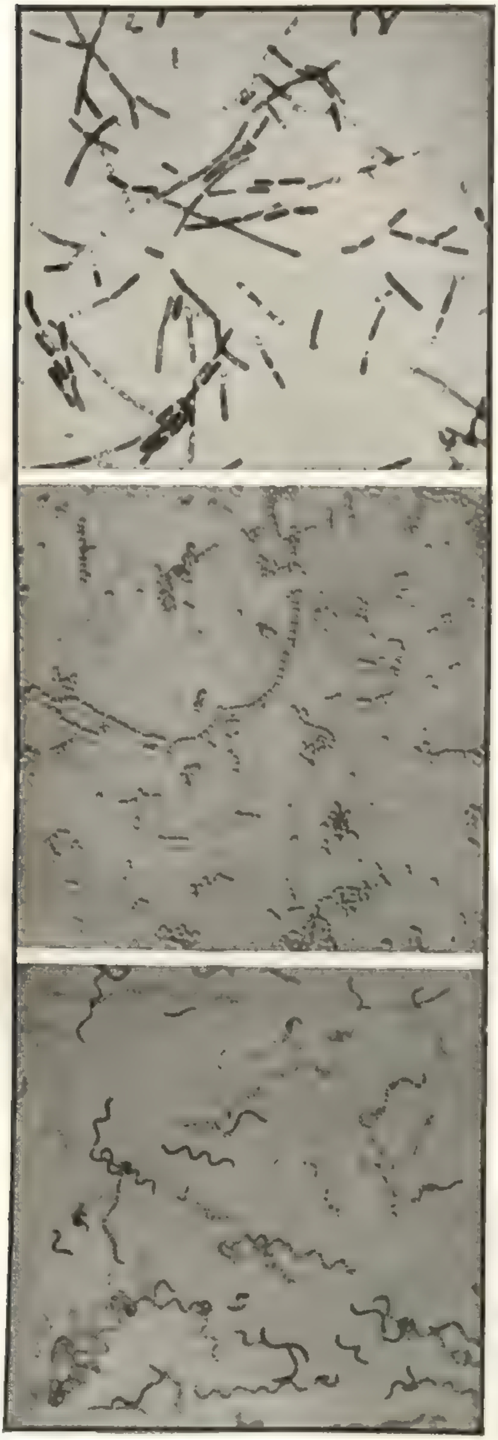
Even with the best of microscopes, you will not be able to see certain very small organisms called *viruses* (vī'rŭs ĕz). Viruses cause such diseases as smallpox, yellow fever, measles, and infantile paralysis. Some of these viruses, however, may be examined with the electron microscope (Fig. 383). There is not yet complete agreement as to what viruses really are. Some scientists think of them as the simplest living things known. Most scientists consider them to be large protein molecules.

Obviously, the large blotches you saw in the Petri dishes were made up of many colonies of bacilli, cocci, or spirilla. Scientists call these three types of tiny organisms *bacteria*. They are our smallest plants (Fig. 383).



381
Here is half of a Petri dish containing nutrient gelatin. Notice the growth of a mold, Penicillium, in the center. Bacteria may also be grown on the nutrient gelatin.

Since bacteria have no chlorophyll, they must get their food from other organisms or from dead material. That is why they are so troublesome. Since they live and feed on other organisms, bacteria may cause diseases.



382 *The three types of bacteria. Rod-shaped bacteria (bacilli) are shown at top; spherical bacteria (cocci) are shown in chainlike colonies in center; spiral-shaped bacteria (spirilla) are found at bottom.* (*General Biological Supply House*)

WHO'S WHO AMONG THE MICROBES

Bacterial organisms are called by various names. They are called microorganisms or microbes because they are small (*micro*) organisms. They are sometimes called germs. We shall use the word *germs* to mean microorganisms which cause disease. Most germs can be seen through an ordinary microscope. Viruses, which cannot be seen under the ordinary microscope, are also microorganisms.

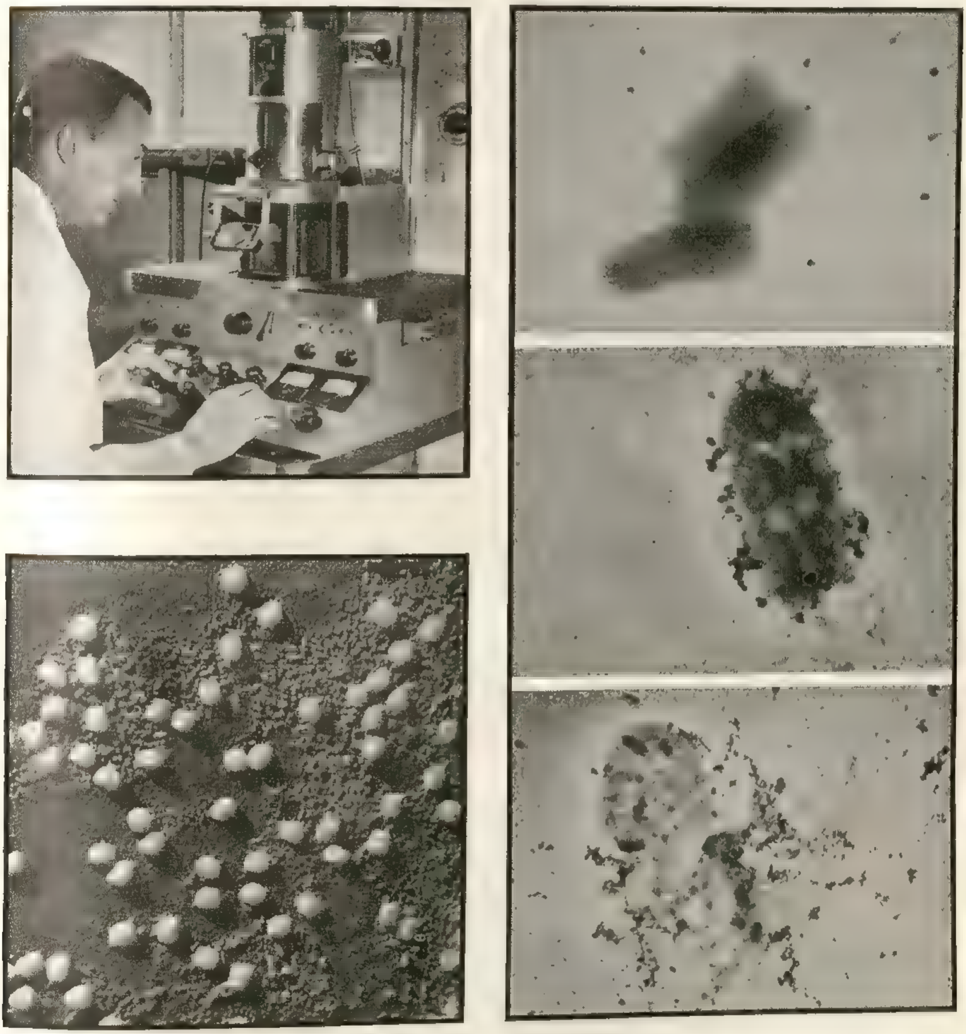
Besides the ordinary microbes such as the bacteria, there are also the Protozoa. The Protozoa are single-celled animals, not plants as are the bacteria.

You are not likely to find any protozoa in the Petri dishes you observe. Protozoa need special conditions to live. Such protozoa as the common freshwater amoeba and the paramecium live in ponds or streams and cause no diseases. Certain protozoa cause malaria, others cause sleeping sickness and other diseases. Many protozoa, like the special kind of amoeba which causes amoebic dysentery, are found in temperate regions.

In Table XIII you will find a list of common microbes and the diseases they cause. Study it carefully.

DORMANT BACTERIA AND FUNGI

Bacteria can exist in a resting stage called *spores* (spōrz). When a bacterium forms a spore, its protoplasm becomes covered with a thick wall, which protects it against unfavorable conditions—heat, cold, dryness, lack of food. Under favorable conditions—warmth, darkness, moisture, and plenty of food—the bacterium breaks through the spore wall and begins to reproduce.



383 *An electron microscope is shown at upper left. A photograph of the viruses which cause fowl pox, taken through the electron microscope, is shown at lower left. The magnification is about 30,000 times. At right is shown a drama which can be discerned under the microscope, and under it only. In top picture two rod-shaped bacteria, magnified 8,500 times, are being attacked by tiny organisms (8 with tiny tails are shown). In center picture the bacteria are being destroyed and in the bottom picture they have been entirely destroyed. Even bacteria have their enemies.* (*E. R. Squibb and Sons*)

Scientists have found bacterial spores in the air, up in the stratosphere, in hot springs, on ice, on dry dust, and in other places where most living things would die. Their thick protective wall permits these bacterial spores to exist under very unfavorable conditions.

DEFENSES AGAINST BACTERIA

Possibly you are somewhat worried by the knowledge that bacteria are found everywhere, especially on your hands and hair. Then, too, you may have noticed how rapidly they multiply under favorable conditions (on nutrient gelatin, in warmth and darkness). Remember, however, that the bacteria on your hands and in tap water were not nearly so numerous as they were in the colonies on the gelatin. On the gelatin, they found the best possible conditions for developing.

Bacteria do multiply rapidly. A bacterium, given warmth, food, and darkness, may divide into two bacteria every 15 minutes. At the end of 15 minutes there will be 2; at 30 minutes, 4; at 45 minutes, 8; and at the end of 8 hours, more than 2,000,000,000! Since they are so small, some of them being 100 times smaller than the period at the end of this sentence, bacteria cannot be seen by the naked eye except when they have multiplied to form colonies.

Despite all the foregoing data, you need not fear. In spite of the bacteria everywhere, you are well protected.

First, most bacteria are either harmless or useful.

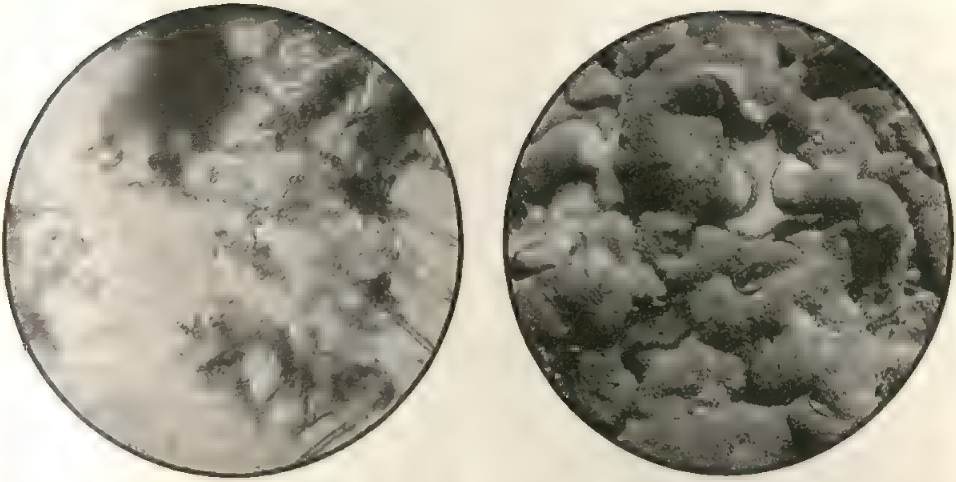
Second, the body protects itself from harmful bacteria.

Third, your body can be helped to overcome bacteria which cause disease.

Fourth, your community stands watch night and day to protect you and

Table XIII. SOME ENEMIES AMONG THE MICROBES

Disease	Microbe	Destroying the germ or its products
Cold	Virus	As yet unsuccessful
Smallpox	Virus	Antibodies produced by vaccination
Infantile paralysis	Virus	As yet unknown
Yellow fever	Virus	Antibodies through injection
Tuberculosis	Tuberculosis bacillus	Streptomycin (not always successful)
Pneumonia	Pneumococcus	Sulfa drugs Penicillin Antibodies in plasma
Typhoid fever	Typhoid bacillus	Antibodies produced by inoculation
Diphtheria	Diphtheria bacillus	Antibodies (antitoxin) produced by inoculation
Tetanus	Tetanus bacillus	Antibodies (antitoxin) produced by inoculation
Malaria	Plasmodium (a protozoan)	Atabrine Quinine
Sleeping sickness	Trypanosoma (trĭp′ȧ nô sō′mȧ) (a protozoan found in Africa)	Arsenicals



384 *At the left, a photograph of the mold Penicillium notatum, which produces penicillin, under the microscope. At the right, a huge colony of Penicillium showing the clear droplets containing penicillin solution.* (*Both, E. R. Squibb and Sons*)

your fellows from disease. The community's fight against microbes is one of man's finest accomplishments and deserves a special chapter, which you will get to later in this book.

Fifth, you will learn how to ward off harmful bacteria and so prevent them from entering your body.

MERITORIOUS MICROBES

You were, we know, impressed by the work of certain of the soil bacteria. You remember how the nitrogen-fixing bacteria added nitrates to the soil. Without certain bacteria this world would be an unfit place in which to live.

BACTERIA OF DECAY

One group of important bacteria is the decay bacteria. They break down dead material so that it becomes useful to other organisms. For instance, they work on a huge tree till it becomes part of the soil. The tree decays only because of the decay bacteria and fungi which use part of it as food.

Certain of these decay bacteria are useful in curing cheese, tobacco, leather, and in preparing flax. In the preparation of flax, for instance, the bacteria cause the decay of the body of the flax plant and leave the fibers. After further treatment, the fibers can be woven into cloth.

Microorganisms like the yeasts are especially useful. Yeasts raise dough for bread by producing carbon dioxide gas in it. Other types of yeasts are useful in producing wines, beer, and alcohol and other products.

MICROBE VS. MICROBE

Have you ever seen a blue-green growth on an orange, on cheese, or on bread? Under the microscope you would find it to be an interesting plant called *Penicillium* (pĕn′ĭ sĭl′ĭ ŭm) which looks like the sample in Fig. 384. Dr. Alexander Fleming noticed this bluish growth when examining a culture of bacteria. What was more important,

he also noted that the bacteria which he expected to find in the culture were missing in the area around the growth of Penicillium. Did the Penicillium produce a substance which killed bacteria? In an important series of experiments, a number of scientists (including Dr. Chain and Dr. Florey) working as a team proved that this was so. The substance which the mold Penicillium produced came to be known as *penicillin*. It soon proved to be a powerful germ killer. English and American scientists went ahead and discovered how to produce penicillin in large quantities. You will read more about it later.

385 *A culture of the mold organism which produces streptomycin. Tubes like this containing nutrient gelatin may be used to grow molds and bacteria. (E. R. Squibb and Sons)*

Penicillin is not the only germ killer produced by microscopic plants. We now know of *streptomycin* (strĕp′tō mī′-sĭn, Fig. 385) discovered by Dr. Selman Waksman of Rutgers University. When given to patients suffering from a certain kind of tuberculosis, streptomycin has been effective in halting the disease. There is also *gramicidin* (grăm′ĭ sī′dĭn) which is produced by soil bacteria. Aureomycin (ôr′ê ō mī′sĭn) and neomycin (nē′ō mī′ sĭn) are among the latest to be discovered, and early reports indicate that they may become most useful. These are a few of the substances produced by microscopic plants which have a great future in the fight against disease.

As you see, some microorganisms, such as the decay and nitrogen-fixing bacteria, Penicillium and its allies, are actually helpful to man. These, however, are only a few of our allies among the microorganisms. Your future studies in science will introduce you to many more.

KEEPING GERMS OUT OF THE BODY

It was a general who said, "Attack is the best defense." With harmful microorganisms, this can be put another way. Destroy the germs before they destroy you. Better yet, keep them out of your body. But how do bacteria enter your body?

ENTRY WITH POLLUTED WATER, MILK, OR FOOD

Typhoid bacilli usually enter the body in polluted water or milk. They may be carried for years by a person who is not himself sick with typhoid. Such a person is called a carrier. Tuberculosis germs may also enter with milk.

Polluted food also permits bacteria to enter our bodies. The housefly in particular is a powerful agent of pollution. Flies feed on garbage—a good breeding place for bacteria—and then carry the bacteria to food which we take into our bodies. Food, therefore, should be kept away from flies.

ENTRY WITH AIR

Some of the diseases which affect our lungs and throats are believed to be spread through the air. Diphtheria is caused by a bacillus which lives in the throat where it produces a poison or *toxin* (tŏk′sĭn). The tuberculosis bacillus at times may enter with the air and lodge in the lungs. And the pneumonia coccus affects the respiratory system. These three bacteria are spread, therefore, by sneezing or spitting. The bacteria may be carried in the droplets from sneezes and coughs by air currents to another person's respiratory system. This method of spreading respiratory diseases is called droplet infection.

Other diseases which are spread through the air are influenza and the common cold. These diseases are not caused by bacteria or protozoa, but by viruses. Therefore, if you have a cold cover your sneezes and coughs with a handkerchief. If you can avoid it, don't get close enough to another person to let your breath carry the cold virus to him.

ENTRY THROUGH THE SKIN

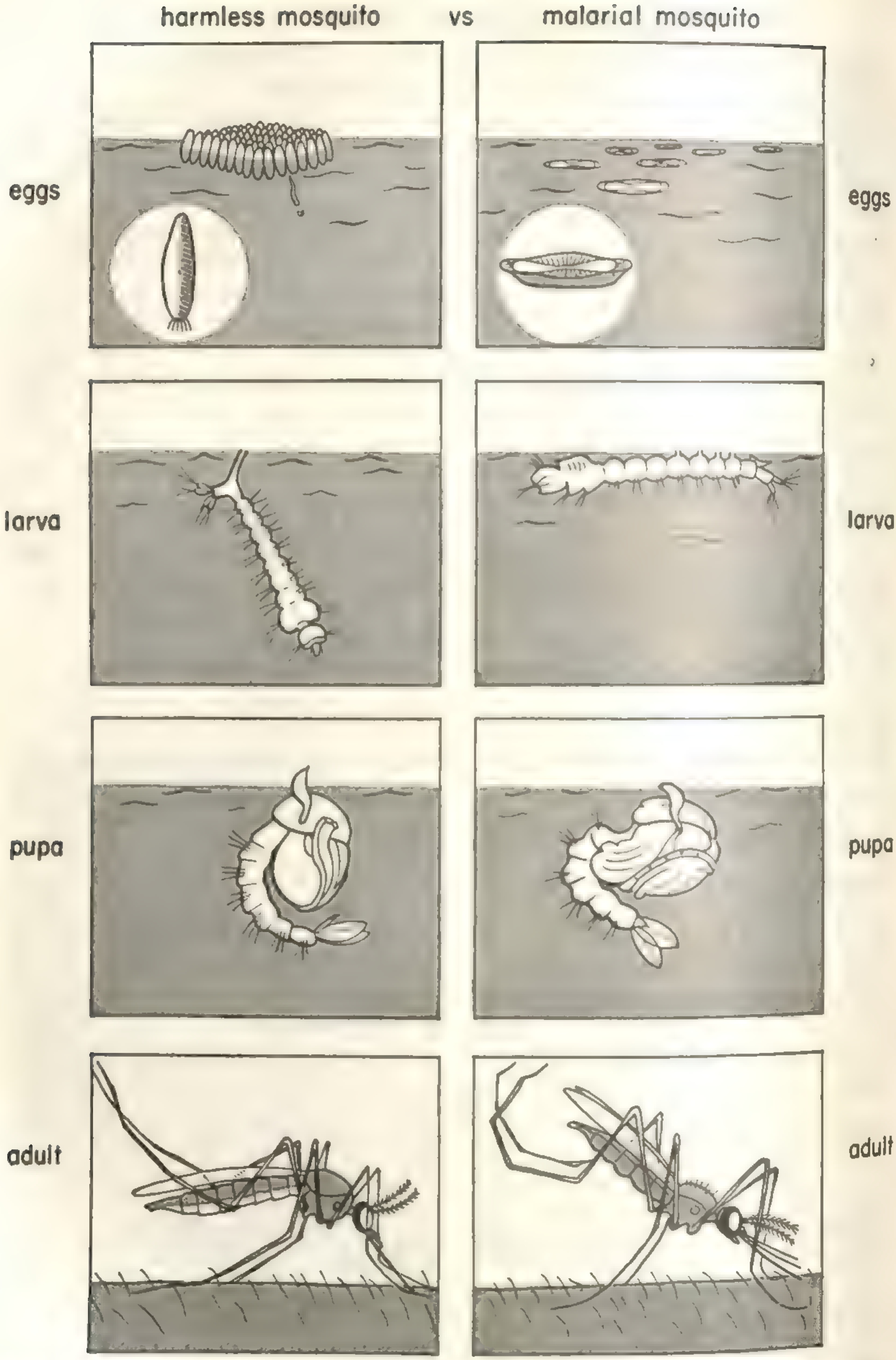
A cut through the skin wall, of course, allows bacteria to enter. The tetanus bacillus enters this way. The tetanus germ cannot grow and reproduce in air. It lives only in deep wounds such as those caused by powder from an exploding firecracker. It may enter wounds caused by stepping on a nail or thumbtack. Tetanus germs may enter if a deep wound is brought into contact with infected soil.

One of the common ways certain disease-producing bacteria, protozoa, and viruses enter the body is through insect bites. For instance, the germ which causes typhus is transmitted by the bite of the body louse. Malaria, the disease which infects the greatest number of people in this world, is transmitted by the malaria mosquito, anopheles (*ȧ* nŏf′*ĕ* lēz, Fig. 386). After piercing the skin to feed on blood, the mosquito injects the protozoa which cause malaria. In the same way aëdes (ȧ ē′dēz), another mosquito, transmits the virus of yellow fever. These mosquitoes generally breed best in warm climates. However, malaria mosquitoes have been found in large numbers even as far north as Ohio.

Body lice which transmit typhus are a sign of uncleanliness. Regular bathing eliminates them. During World War II, DDT was sprayed on clothing and body to kill the lice which infected soldiers and civilians who could not bathe frequently.

For protection from mosquitoes, screens should be put up in early summer. They should also be painted with DDT solution. If your home is near a lake or swamp where mosquitoes breed, killing the mosquitoes becomes a community problem. The swamps may be drained, or sprayed with DDT, or oil may be spread on the water. The oil kills the mosquito larvae which breathe air from the surface of the water.

Some microorganisms do not need to get past the skin to cause trouble. For instance, there is the so-called athlete's foot. This is caused by a plant belonging to the fungi. The fungus of athlete's foot is found on floors of places like locker rooms and swimming



386 *Compare the ordinary mosquito with the malarial mosquito. Notice the position of the malarial mosquito as it prepares to pierce the skin. How else do they differ?*

pools. Although the fungus may attack other parts of the body, it generally feeds on the skin on the base of the foot and between the toes where it may cause extreme itching and then sores. Therefore, if you do go to public baths, wear rubber bathing slippers. And your own bathroom floor should have a wash with commercial chlorine water every few weeks.

INFANTILE PARALYSIS

You can see how difficult it is to try to prevent a germ disease if it is not known how the germ gets into the body. For example, it is not known how the virus of infantile paralysis enters our bodies. Some people believe that the virus is either water-borne or that it enters through the respiratory system. The virus appears to be most active during the warm months, especially July and August. It is best to stay away from areas where there are cases of infantile paralysis.

COMMON COLD—COMMON AILMENT

Practically every person in this world has had a common cold. The symptoms are headache, tiredness, running nose, perhaps a sore throat, sneezing, and coughing. This uncomfortable illness is believed to be caused by a virus. It is easily spread by sneezing and coughing.

Although scientists are hard at work on the problem, there is no way at present of protecting people from colds. Till that way is found—and if it can be found, science will find it—you must try to prevent any cold you do get from becoming serious. If you take immediate care of it, it will not last long. This means going to bed at once and taking hot drinks and liquids. If the cold symptoms do not begin to disappear in a day, if there is a sore throat, do not delay calling the doctor.

ON THE SAFE SIDE

Let us decide to be on the safe side. It is not your job to be the doctor. Your job is to keep yourself healthy through preventing disease. We should be on guard to keep microorganisms out of our bodies. We should:

1. See that our water and milk are kept free of germs.
2. See that our food is prepared and kept under sanitary conditions.
3. Wash before meals.
4. Keep clean.
    a. Bathe regularly to keep the skin clean; that is, at least once every second day.
    b. Keep teeth clean.
    c. Keep nails cut. Dirt under nails is a good carrier for bacteria.
5. Treat cuts and bruises immediately by washing them with soap and clean water. Then bandage loosely. (See Chap. 34 for first aid.)
6. If possible avoid persons who have diseases which are easily spread, such as colds.
7. Read "Symptoms" below.

You can be responsible for rules 3, 4, 5, and 6, but you may not be able to control completely rules 1 and 2. On the farm, you may have a good deal to do with keeping your drinking supply safe. But in many places, inspection of water, milk, and food will be the job of the community.

That does not mean your responsibility is gone. It just takes another form: You must be on the watch to see that your community does its job (Chap. 33).

SYMPTOMS

Almost all diseases produce their characteristic symptoms. A symptom is a sign of a specific disease. Many diseases have symptoms in common. Pneumonia and colds may begin with coughs,

headaches, fever. Measles and diphtheria may begin with headaches and fever. So may typhoid, scarlet fever, and many others. What you must do is clear. When you feel ill, when you have a headache, chill, abdominal pain, or fever, tell your parents or teacher about it immediately. If you have an abdominal pain, do not take laxatives. Laxatives may cause serious difficulty in an attack of appendicitis.

Your teacher or parents will take the proper precautions. If the illness lasts overnight, the doctor should be called. If there is a high fever, you should not wait; call the doctor at once. Obeying this last rule would have saved thousands of lives in the past. It should save many in the future.

Go to the doctor, especially if you have any pain which does not disappear within one or two days. Go to him if you have a growth on your skin which does not disappear within a week or so, or one which keeps growing larger. Go to him if you are suffering from regular constipation. Go to him whenever you are worried about your health. He is the expert.

BODY DEFENSES AGAINST DISEASE

You know now how germs, either the helpful or harmful kind, enter your body. In your experiments with bacteria, you found them present on your hands, in the air, and in the water. They are everywhere. Most of them are harmless, but some are disease-producing.

FIRST LINE OF DEFENSE

In studying the preceding chapter, you learned that flat cells like those on the inside of the cheek cover the entire surface of the body. Your skin consists of several layers of flat cells. These are your first line of defense against bacteria. As long as your skin is whole, bacteria cannot get through it into your body.

What happens if bacteria get into the mouth? They do get in even though the food you eat and the dishes you use are the cleanest. But they do not get into your body tissue easily for there are protecting cells which cover the surface of your gullet, your stomach, and intestines (Fig. 375). Cells similar to those in the cheek protect the inside of your nose. These inner cells lining your cheek, gullet, stomach, and intestines form membranes called the *mucous* (mū′kŭs) membranes. Furthermore, these cells produce a sticky substance, the mucus, which catches the bacteria and is thought to kill some of them. Finally, when many bacteria are collected on the mucous membrane of the nose, it becomes irritated and a sneeze results. Do you see now why you should always use a handkerchief when you cough or sneeze? If you do not, you will send the bacteria into the air toward other people.

Should the bacteria reach the stomach, however, the acid gastric juice will destroy some of them. Sometimes, however, too many bacteria enter the stomach with polluted water or food, or in the form of spores. The gastric juice may not be sufficient to do the job of killing them. Then we must depend on other defenses.

MAINTAINING THE FIRST LINE OF DEFENSE

It is important to maintain a whole layer of covering cells. But how can an active boy or girl of your age do that? Many times you bruise or cut yourself in games or on hikes. If you

get a bruise in which the skin is broken or a cut, you will have to make an artificial covering. First, wash the cut with soap and water. If the cut is small, you may use a band-aid; if it is large, a loose bandage may be put on till a clot forms. In this way, you temporarily repair the break in the skin. A tight bandage may interfere with repair by keeping air from the wound and by reducing blood circulation.

SECOND LINE OF DEFENSE

Suppose, however, you did not cover a cut or a bruise in time. What might happen? Sometimes the wound may become infected. Pus is evidence of infection. How does pus form? If we examine a sample of pus under the microscope, we find that it contains bacteria, and many living and dead white blood cells.

When bacteria get past the covering cells, your first line of defense, the white blood cells move to the point of invasion. White blood cells, you remember, circulate through the body in the blood. They move out of the capillaries and among tissue cells somewhat like amoebae. White blood cells engulf bacteria. They die when they have destroyed a good number of the invaders. Dead bacteria and dead white blood cells form part of the pus.

So you see, pus is a sign of a battle between white blood cells and the invading bacteria. This battle really is a battle against infection, a word which means that bacteria have entered and are multiplying in a certain part of your body.

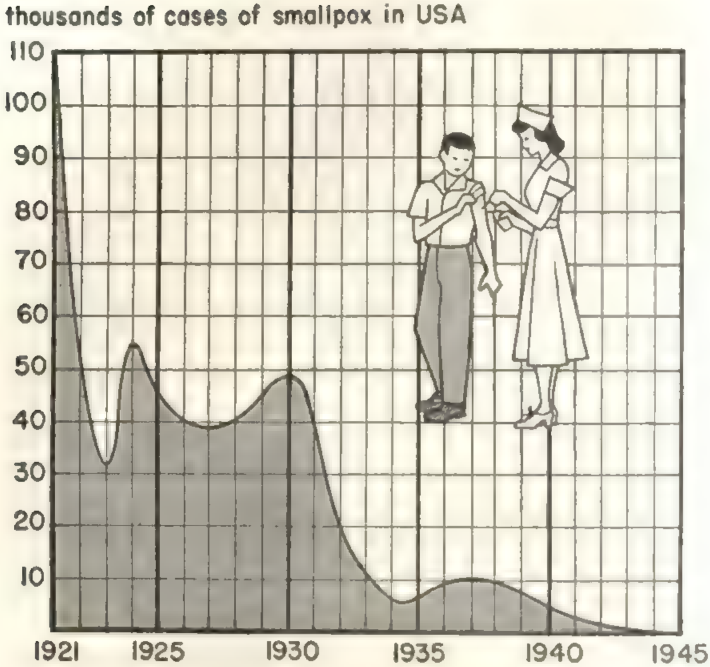
Do you remember how many white blood cells there are in your body (Chap. 30)? About $\frac{1}{13}$th of your body weight is blood. And a drop of blood contains about 5,000–7,000 white blood cells. How many white blood cells have you? You can see that this is a huge number. White blood cells are your second line of defense.

Sometimes, however, microorganisms get past the first and second lines of defense. This may happen when bacteria or protozoa enter in large numbers into parts of the body where they can multiply rapidly. This is especially true of many common diseases such as typhoid fever. Suppose white blood cells cannot cope with the bacteria? Is this the end? Not at all.

Your body can be made to develop certain substances which either kill the microorganisms or counteract the poisons they produce. Let us see what they are.

CHEMICAL DEFENSES IN THE BODY

For instance, if you have a vaccination mark on your arm or leg, you will not get smallpox within four to eight years after the vaccination, no matter how many times the smallpox virus enters your body. In vaccination against smallpox, a small amount of the virus of cowpox, a similar disease, is placed in a small scratch on your arm. Your body is stimulated to produce a chemical defense against this virus. Your body produces substances called antibodies, which destroy the cowpox virus. Since cowpox and smallpox are closely related viruses, these stored antibodies are able to destroy any smallpox virus that enters while the antibodies still exist in the body. Medical scientists then say you are immune to smallpox. However, antibodies formed against smallpox or other diseases may not last all your life. As stated previously, smallpox vaccinations generally provide safety only for four to eight years. Thus when an outbreak of smallpox occurs, it is well to be revaccinated (Fig. 387).



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The decline of smallpox in the U.S. What has brought this decline?

Immunity to typhoid fever, diphtheria, yellow fever, or cholera, is not produced by vaccination. Instead, dead or weakened bacteria (or a virus in the case of yellow fever) are injected into the body. This is known as inoculation. The body then produces antibodies against these organisms. If you have been inoculated for all these diseases within the past few years, you may have these antibodies in your blood. Some antibodies do not remain in the body for more than a year; others may last for a very long time. During World War II, many soldiers received these and other inoculations. It is wise for travelers going into foreign countries to be immunized by inoculation against typhoid and yellow fever, and by vaccination against smallpox.

HAVING AND ACQUIRING IMMUNITY

When these methods—vaccination and inoculation—are used, you actually get a slight attack of the disease. You probably have realized that an actual attack of one of these diseases also causes the body to produce antibodies. For instance, an attack of typhoid fever usually makes a person immune for life. In most cases the body builds protection against a second attack of certain children's diseases like measles. During the disease, the body develops antibodies which prevent future attacks.

There are two ways, then, of acquiring immunity:

1. By getting and recovering from the disease; for example, measles.

2. By having antibodies produced in you by vaccination or inoculation; for example, typhoid fever.

On the other hand, some people never get certain diseases even if the germs of the disease enter their bodies. These people have a *natural immunity* to the diseases. This is probably present at birth. Whether you have an acquired or natural immunity, it is an immunity produced by antibodies.

HELP FROM ANIMALS

If you do not have an acquired or natural immunity, there is still another way of combating certain diseases. Antibodies produced in other animals can be injected into our bodies. The bacteria which cause some diseases stay in one place in our bodies and produce poisons or toxins. Diphtheria germs, for example, stay in the throat; tetanus germs in the wound in which they are introduced.

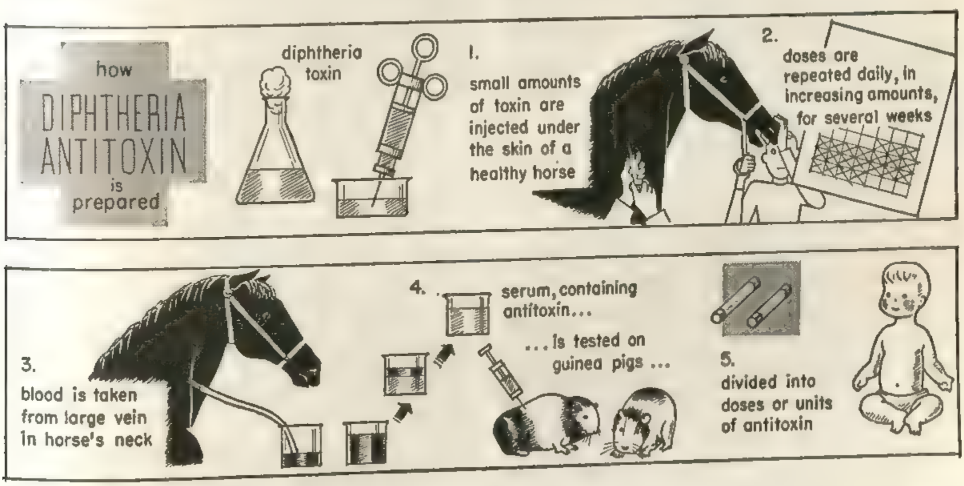
If these bacteria are injected into a horse, for example, the horse will produce in his blood an antibody to the toxin (Fig. 388). Antibodies to toxins are called *antitoxins*. An antitoxin neutralizes a toxin and makes it harmless. These antitoxins are to be found in the serum, a straw-colored liquid which remains after the horse's blood clots. The serum is stored in vials.

When a person is ill with tetanus or diphtheria, serum containing antitoxin produced by the horse can be injected into the patient to counteract the toxin produced by the diphtheria or tetanus bacteria. Sometimes tetanus antitoxin is given to people with gunpowder wounds to prevent the occurrence of tetanus. In the same way, we can borrow the antibodies produced by animals for other diseases such as pneumonia, typhoid fever, and typhus.

Many lives have been saved by the antibodies borrowed from horses, sheep, rabbits, and guinea pigs. These animals are in the service of mankind.

CHEMICALS AGAINST MICROBES

For some diseases, we know of no antibodies or antitoxins. For such diseases, there are different methods of destroying the germs which cause them. We may use substances produced by man or by plants. You have used iodine to destroy bacteria. You probably know that chlorine is used to kill microorganisms in drinking and swimming water. Chlorine also will kill the athlete's foot fungus. You know that the sulfa drugs, such as *sulfanilamide* (sŭl′fȧ-nĭl′ȧ mīd), are used against certain infections like pneumonia. Penicillin and streptomycin are used against certain diseases (Table XIII, p. 570). *Quinine* (kwī′nīn) and *Atabrine* (ăt′ȧ brĭn) are used against malaria.



388 *The story of the preparation of diphtheria antitoxin. This drawing might be entitled "Help from Animals."*

The list of chemical cures is a long one. New ones are constantly being discovered. Discoveries of this kind indicate one of the ways man's intelligence has been used to increase his life span.

CANCER—CAUSE UNKNOWN

Finding the cause of disease is a big problem for doctors and medical researchers. Scientists are still searching for the causes of such diseases as cancer, rheumatic fever, arthritis, and high blood pressure. Possibly these diseases are not caused by micro-organisms.

Louis Pasteur, the great scientist, gave us the theory that microorganisms cause disease. We know now that rickets, scurvy, pellagra, beriberi, anemia, and other diseases are caused by lack of certain nutrients—not by germs.

It is a widely accepted theory that cancer is not caused by a germ. In cancer, certain cells which ordinarily do not divide, begin to divide rapidly. Then they form a shapeless lump or cancer. During the growth, they may interfere with the normal activity of some of the organs of the body. Finally, parts of certain types of cancerous growth may get into the blood stream and form cancers in other parts of the body.

Experiments on animals have shown that constant irritation on parts of the body may produce cancer. To be on the safe side, therefore, wear loose, comfortable clothing. Careful study of cancer in animals and humans has shown that there are many early signs of cancer development. For instance, some cancers of the skin start with a small molelike growth which does not disappear but keeps growing. This does not mean that every pimple, mole, or swelling is the start of a cancer. It merely means that, to be on the safe side, a skin growth which does not disappear within a week or so should be called to a doctor's attention, especially if it keeps on growing. An annual medical examination is also very useful because cancer in its early stages may be detected.

Cancer in its early stages is curable. Spread this statement wherever you go. X rays, radium, surgical treatment, or a combination of these is effective during the early stages. Recently scientists have found a number of ways of discovering the presence of cancer. They may test sputum from the mouth, or they may test urine. In the sputum or urine they may find certain cells characteristic of cancer. These tests are quick, inexpensive, and completely painless. If someone is worried about cancer, he can get one of these tests now. If the test shows no cancer, he can stop worrying. If an early cancer is discovered, it can be cured. Another test has recently come into wider use. This tests the time in which blood clots. It has been found that the blood of people who have cancer does not clot as quickly as does the blood of those who do not have cancer. This test, like others, needs careful analysis by experts who have made cancer their special field.

Early cancer can be cured. Watch for signs which often point to cancer. What are these signs?

1. A growth (pimple or mole or hard lump) which does not disappear and, generally, increases in size.

2. Signs of constant constipation; that is, poor bowel movement in a person who has had regular bowel movement.

3. Any unusual discomfort or discharge (colorless or tinged with blood) in any part of the body.

These signs may not mean cancer—

but only the doctor can tell you so. And if the doctor discovers a cancerous growth, he can cure the cancer—if the patient has reached him early enough.

Many scientists are now working on the fundamental problem: What causes cancer cells to divide? They are also using radioactive substances to discover how the protoplasm of cancer cells functions.

DISEASES WITHOUT GERMS

There are diseases which are not caused by microorganisms. The causes of some of these diseases are definitely known.

Diabetes is caused by a lack of the substance *insulin* (ĭn′sŭ lĭn), which is produced by the pancreas. Insulin is one of several substances called hormones, which are produced by glands and sent directly into the blood. Diabetes results when the pancreas does not produce enough insulin. Insulin enables the body to oxidize sugar and fats. Without insulin, therefore, the body is not able to oxidize all the sugar it makes or receives in food. As a result, unoxidized sugar is found in the urine of diabetic people. Diabetes is now treated with injections of insulin. By having insulin injections and by following a prescribed diet, a diabetic can live a nearly normal productive life.

Other diseases which apparently are not caused by germs are high blood pressure and certain types of heart disease. High blood pressure is caused by the decrease in the diameter of the small arteries. The heart, therefore, has to pump harder; that is, exert more pressure to send the blood through narrower arteries. When people suffering from high blood pressure become excited, the blood pressure may go so high as to cause serious illness. No definite cause or cure for high blood pressure is known at present. Resting and careful living to avoid excitement or worry appear to be helpful in combating this disease.

As the body grows older, the circulatory system becomes affected. After all, the heart beats day in and day out; the blood vessels are affected by the constant surge of blood in them. In some people, the walls of the arteries become hard because of the deposit of calcium compounds in them. This is known as hardening of the arteries. Hardened arteries lose their elasticity and do not expand and contract easily with the surge of blood in them. Thus they do not help push the blood ahead. The work is left entirely to the heart which is strained by the extra exertion.

The diseases of the circulatory system and other diseases of old age have been called degenerative diseases. They come with the wearing out of the body. Since more and more people are escaping diseases caused by bacteria, viruses, and protozoa, they live long enough to be affected by the degenerative diseases. Very little is known about the specific causes of these degenerative diseases. Your generation of scientists will have much to contribute in studying them. In recent years a new science called geriatrics (jĕr′ĭ ăt′rĭks), devoted to the study of conditions of old age, has grown up.

OTHER CURES TO COME

The degenerative diseases are not the only ones for which cures are needed. We need a cure for tuberculosis.

No doubt you have heard of the rest cure for tuberculosis. This is not a cure in the true sense. The rest cure, which merely arrests the growth of the tuberculosis germ, consists of good food, rest, and fresh air. Probably every adult

has had a very slight attack of tuberculosis. But the body has overcome the attack and enclosed the germs in a capsule or tubercle (tū′bẽr k'l), as it is called. Overwork, poor food, poor air may lower the body's defenses enough to give the bacteria another chance to develop. Recently, however, streptomycin has been shown to be effective in halting the development of the tuberculosis bacillus in certain forms of tuberculosis.

For infantile paralysis, too, there is still no cure. If it is diagnosed in its early stages, however, the disease may not have its usual crippling effects. Indeed, many diseases like tuberculosis and infantile paralysis may be overcome if they are caught early enough.

RADIOACTIVE SUBSTANCES AND HEALTH

All over the country scientists are using the new tool, radioactive substances, to investigate diseases and combat them. Because of this new tool, many diseases which plagued the last generations will not plague yours (Fig. 389).

TRACING SUBSTANCES

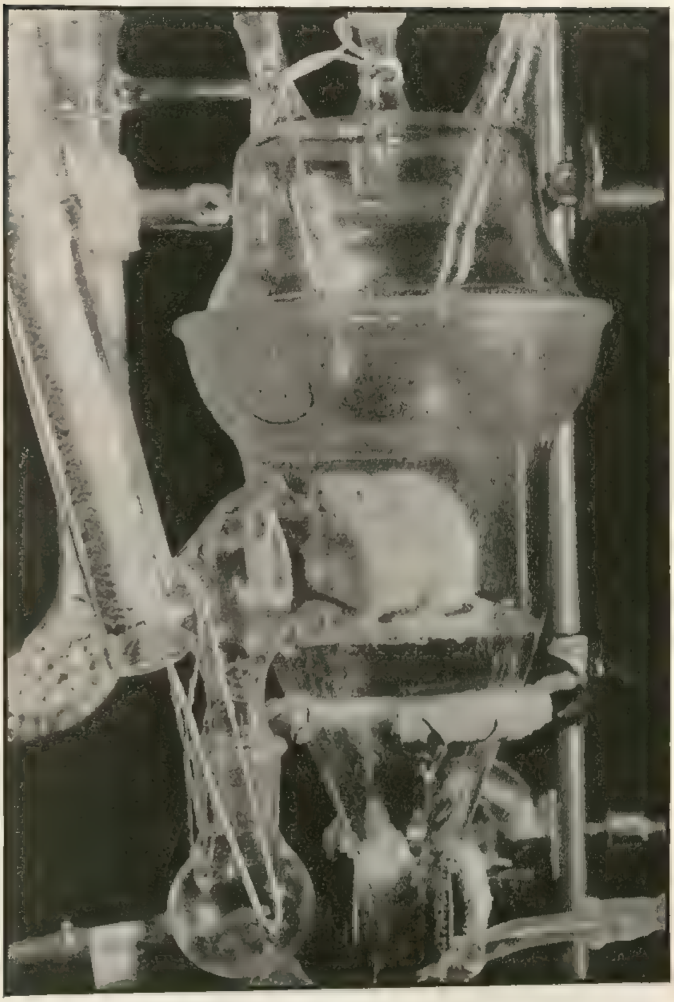
Radioactive substances can be taken into the body in food or they can be injected into muscles or the blood stream. Once inside the body, their travels can be traced by Geiger counters outside the body. We shall know more about treating deficiency diseases when we know where food substances go once they are absorbed from the intestine.

At the California Institute of Technology scientists have been using radioactive nitrogen to trace simple proteins in our diet. They have found that certain proteins, like glycine (glī sēn′), furnish the nitrogen to make the hemoglobin of our red cells. Other simple proteins traced in the body have been shown to form complex proteins which later form antibodies. At the University of Chicago, radioactive phosphorus in certain compounds has been traced to its place in the nervous system. You may have read newspaper accounts about the tracing of radioactive iodine to the thyroid gland, where it is used to form the hormone thyroxin.

It also has been found possible to trace the path of poisonous substances in the body. Radioactive arsenic has been traced in the bodies of experimental animals and found to be concentrated in liver cells. The toxin (poison) of dysentery has been traced at Johns Hopkins University where it has been shown that most of that toxin also is taken up in the liver.

RADIOACTIVE SUBSTANCES AND DISEASE

A report from the Massachusetts Institute of Technology begins with the statement: "It is inconceivable that the research we have undertaken could have been attacked without the use of radioisotope tracers." The word *radioisotope* refers to elements which have been made radioactive. For instance, the scientists at M.I.T. have found that cancerous tissue will collect five to seven times as much amino acid (substance out of which proteins are built) as will normal tissue. Since it is known that radioactive substances help destroy cancer, this discovery may lead to a method of destroying cancerous tissue by concentrating radioactive substances in it. You may have read of recent attempts to concentrate a radioisotope of iodine in cancerous tissue of the thyroid. Radioactive phosphorus has also been concentrated in bone tissue in order to destroy the increasing



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Laboratory mice, after taking food "tagged" with radioactive carbon at Los Alamos Laboratory, New Mexico, are placed in all-glass metabolism cages which collect exhaled air and other body excretions. By following path of the radioactive carbon with Geiger counters and other instruments, scientists learn new facts about the workings of the body, of man as well as the mouse. (*Atomic Energy Commission, Los Alamos*)

number of white blood cells in the cancerous disease leukemia. These last two attempts in using radioisotopes of iodine and phosphorus to cure cancer have been only partially successful.

By using radioactive iron, various hospitals are studying how long red blood cells survive in blood stored for purposes of transfusion. Since the iron enters the red blood cells as part of the hemoglobin, a Geiger counter can determine when a red cell dies because, in doing so, it releases the radioactive iron. Radioactive iron also is being used to study anemia, a disease caused by lack of a sufficient amount of hemoglobin.

Many studies with radioisotopes, too numerous to mention here, are being conducted in laboratories throughout the country to answer such questions as:

What is the difference between a cancerous cell and a normal cell?

What happens to disease bacteria which have been fed radioactive substances?

What happens to bacteria when they enter an experimental animal?

How does the body develop immunity to disease?

How does penicillin destroy bacteria?

How does the body use different vitamins?

What is old age?

The answer to these and other questions will come sooner or later and will result in longer life and more vigorous health. Perhaps one of you will have a part in the solution of these problems.

RESULTS COUNT

In this chapter you have seen how you benefited from the results of the work of thousands of scientists. The application of their discoveries can be summarized in the graphs shown in Figs. 390, 391, and 392.

What is behind these graphs?

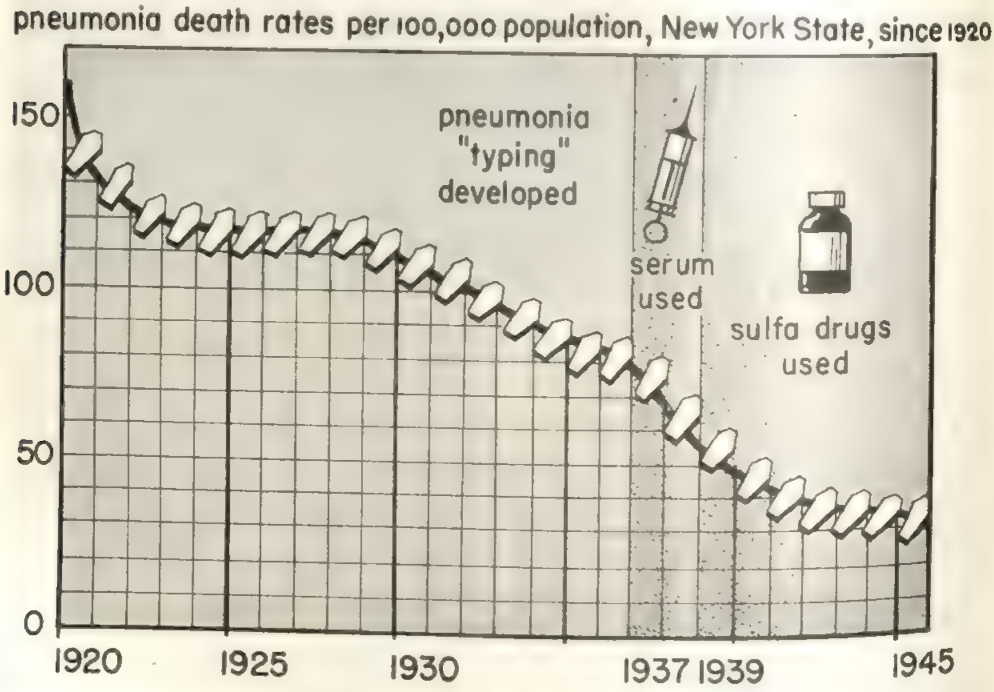
Behind them is the fact that man has learned to control many germ diseases. First, he learned to recognize germs and the diseases they cause. Then, he learned to prevent their entry into his body. Finally, he learned how to kill them if they succeeded in entering the body. Now man is battling diseases like cancer, heart diseases, and other diseases not caused by germs.

Because bacteria travel from person to person, disease prevention is a fight in which the entire community must join. In this fight against disease, you will play your part. In the next chapter, "An Ounce of Prevention," you will learn what your part should be.

GOING FURTHER

1 *Examining bacteria.*

1. Place about twenty cooked peas or beans in a glass of water and allow them to stand for about a week. There will be a foul odor. But there will also be a mass



390 *Notice how the number of deaths from pneumonia have dropped. Pneumonia "typing" means testing for the kind of pneumonia so that the proper serum, containing antibodies, may be used.*

of decay bacteria in the scum which forms. Be sure to heat one end of the needle red-hot before and after you insert it in the glass. This will kill any bacteria. Then with the needle pick up some of the scum and spread it on a spot near the center of the slide. Allow the slide to dry. Then pass the slide slowly through a low flame four or five times. Stain it with a few drops of methylene blue. (You can get this stain from a biological supply house.) After one minute rinse the slide with water several times and dry it. You have prepared a slide of bacteria. Examine this slide under the highest power of a microscope. You may find bacilli (rod-shaped forms), cocci (spherical forms), and even spirilla (corkscrew-shaped forms, Fig. 428).

2. If your teacher has some prepared, stained slides of these forms, examine them.

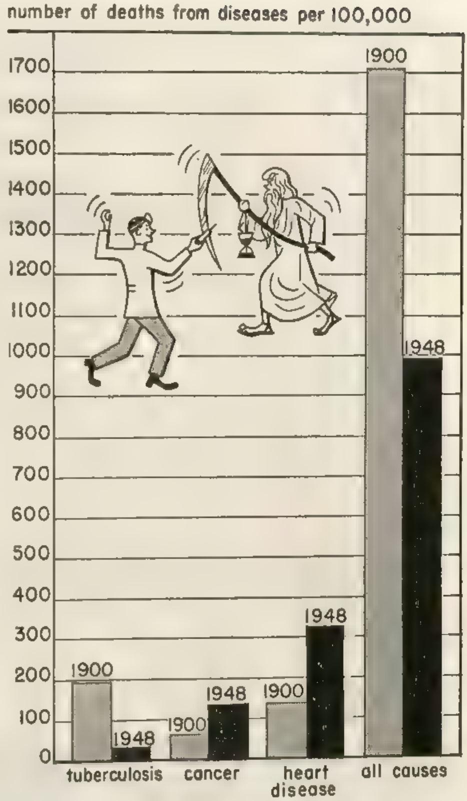
3. Have you examined the bacteria in the colonies in the Petri dishes which you prepared in doing the experiment on pages 566–67? Examine the slide you have prepared under high power. Ask your teacher to help you use oil immersion if an oil immersion lens is available in your school. Can you find the different types? (See 1 above.)

2 *Growing Penicillium.* Place an orange or a lemon in a moist jar. In a week or so, you will be able to examine the mold that has formed and to discover its interesting structure. Can you see the spores?

3 *Writing a report.* Your science class or English class would be interested in a report on these topics. 1. Destroying the invisible enemy. 2. Three lines of body defenses. 3. Closing the portals of entry to bacteria. 4. Killers of mankind. 5. Cancer and its control.

4 *Words are ideas.* Can you use these words in sentences which will give their meaning? Use the glossary.

bacteria	antibody	quinine
spirillum	antitoxin	geriatrics
coccus	penicillin	virus
bacillus	Penicillium	protozoa
inoculation	toxoid	vaccination
streptomycin	serum	pus



391 *This chart compares the death rates from three major diseases in two different years of the twentieth century. Scientific advances have greatly reduced the* total *death rate since 1900. Thus the average person tends to live longer, and there are increased numbers of older people living today. As a result death rates in 1948 from cancer and heart disease, both of which afflict older people, have become higher. Tuberculosis is more likely to strike younger people.*

5 *Put on your thinking cap.*

1. How would you kill bacteria if you were in these situations? (a) You are on a farm and suspect the well water. (b) You have just cut yourself.

2. In 1920 in a small town in Ohio, 1,000 people became ill with typhoid fever. Thirty died. If you were the Health

Inspector, what would you suspect to be the source or sources of the bacteria? Why?

6 *Test yourself.* In your notebook, complete the following statements with an accurate word or phrase. Do not mark this book.

1. Bacteria which cause human diseases grow best at about ...... Fahrenheit.
2. Rod-shaped bacteria are called ....
3. Man could not exist without the work of useful ....
4. The ...... bacterium grows best when it is not in the presence of air.
5. ...... are one-celled animals.
6. The cells of the body engulf bacteria and other ...... microorganisms.
7. ...... is the process of injecting dead or weakened bacteria into the body.
8. ...... can be cured by means of X ray when it is treated early.
9. ...... can be transmitted through polluted milk or water.
10. The death rate due to ...... diseases has decreased greatly during the past ten years.

7 *Adding to your library.* You will find *Microbe Hunters* by Paul De Kruif, Harcourt, Brace, 1926, a fascinating account of the pioneers who set us on the road to the conquest of bacteria. The experiments of Pasteur, Koch, and Metchnikoff are set forth clearly.

392 *A graph showing roughly the life expectancy of children born in the years 1200–1949. How much has life expectancy increased since 1830, your great-grandfather's time?*

CHAPTER 33

AN OUNCE OF PREVENTION

As you are aware, it is quite common for lawbreakers to be arrested. Yet one woman who was arrested in the early part of the twentieth century had stolen nothing; she had killed no one; she had committed no ordinary crime. Nevertheless, she had to be kept under close watch in a special room on Ward's Island in New York City until she died.

Typhoid Mary, as she was called, was a danger to other people in the community. Although she did not have typhoid fever herself, she was a living reservoir of typhoid germs. She was a "carrier." Deadly typhoid germs got into the food and water she handled. Many outbreaks of typhoid fever were traced directly to her.

The community must protect its citizens against disease. This is one of its first duties. The community government has power to enforce its laws against groups as well as individuals. It can condemn houses, condemn milk, condemn food, deny licenses to food handlers, and arrest "carriers," in the interest of health. It must supply pure water and pure food. It must stand constant watch against disease. As a member of your community, you have a responsibility for guarding your own health and that of your neighbors.

SAFEGUARDING FOOD

How does your community stand watch over the water, milk, and food supply? What is your part in this all-important activity?

INSURING SAFE MILK

Have you ever seen a public health inspector in your town or city stop a milk truck and sample bottles of milk from it?

In state and city laboratories every day, technicians sample milk from bottles and make a count of the bacteria in it. Generally, they find that the bacterial count (the number of bacteria) is low enough so that the milk is safe to drink. Is this an accident? Of course not. Many states have laws which require that milk for drinking be *pasteurized* (păs′tẽr īzd). One method of pasteurization is to keep the milk at a temperature of about 145° F. for twenty minutes and then cool it rapidly. This procedure kills dangerous germs.

Tuberculosis, typhoid, diphtheria, scarlet fever, and other types of bacteria are kept out of milk because laws in many states require: (1) regular inspection of dairy cows by health officers and the destruction of unhealthy cows; (2) regular inspection of workers who handle milk; (3) sanitary methods of milking and, sometimes, the use of milking machines; (4) icing of the milk until it is delivered to the bottling plant or creamery; (5) regular inspection of bottling plants and creameries. In the bottling plant, the milk is sealed in sterilized containers after pasteurization (Fig. 393).

Of course, properly handled raw milk from perfectly healthy cows may be free from dangerous amounts of harmful germs. If you want to avoid invasion by the bacteria of tuberculosis, undulant fever, typhoid fever, or other diseases, you will insist on pasteurized milk.

SAFEGUARDING MEAT

Fig. 394 shows a piece of meat which has been rejected by health officers. Compare it with one that has been accepted. The pieces of meat would look the same to the naked eye. But they do not look the same under the microscope. The rejected meat has tiny round worms called *trichinae* (trĭ kī′nē) enclosed in tiny capsules or *cysts* (sĭsts). If these worms are not killed by thorough cooking, they will break out of the cysts and enter the muscles of the human body—causing pain and fever, and the disease *trichinosis* (trĭk′ ĭ nō′sĭs). If the infection is severe, the muscle cells will never be as efficient as before.

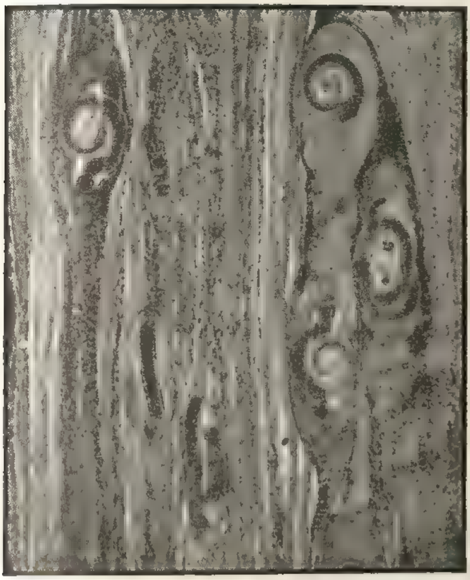
To avoid trichinosis and similar diseases, do two things. First, eat only inspected meat. Modern meat packers accept and sell only inspected meat.

Second, always cook meat thoroughly (especially pork) before eating it. Thorough cooking kills the worm which causes trichinosis, and other worms which may be present in the meat.

YOUR CONTRIBUTION

It would be useless to supply you with inspected food unless you use

393 *Making milk safe. The milking machine the farmer is holding at the left makes for efficient clean milking; the bottled milk at the right has been inspected and pasteurized to keep it clean and safe.* (*Both, Standard Oil Co.* (*N.J.*))




394 *At the left, meat infested with trichina worms. At the right, healthy meat. Cooking meat thoroughly destroys the worms.* (*General Biological Supply House*)

your knowledge of the way bacteria behave. Harmful bacteria can live and develop on meat and other foods. You know that these bacteria are everywhere. Is it wise to keep food covered and protected from bacteria?

You know that flies carry bacteria from garbage and sewage. It is a good application of science to kill flies and keep them away from food. How?

1. By careful screening.

2. By keeping manure piles and garbage dumps far from the house. Calcium hypochlorite (chloride of lime) should be placed on the farm garbage dump. Garbage pails should be washed out at least once a week.

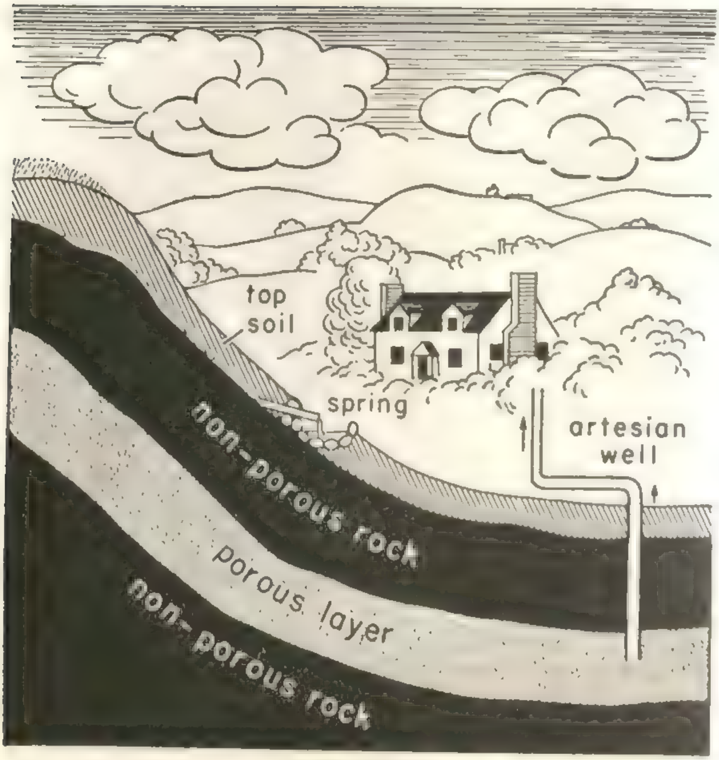
3. By spraying fly killers, or by painting the screens and window sashes (and other places where flies gather in the house) with a 5 per cent DDT solution. Be careful, however, to follow the directions for its use.

4. By placing food on ice or in the refrigerator to keep it cool and thus discourage the growth of bacteria. Food can also be preserved in a deep freezer which keeps the temperature so much lower than the ordinary refrigerator as actually to freeze the food.

Some food today is preserved by dehydration, that is, by removing the water from the foods. Since bacteria need warmth and moisture to develop, removing either of them preserves the food. In refrigeration, warmth is removed; in dehydration, moisture is removed.

In canning, some foods are preserved by being heated to a temperature which kills bacteria. Then the inside of the sterile can is kept free of bacteria by sealing it while the food is hot. Once a can of food is opened, what is not eaten should be kept in the refrigerator.

Meats may also be preserved by different types of curing. Some meats are placed in smoke from a fire in which the preservative creosote is present.



395

A diagram showing the source of spring and artesian well water. Why is artesian well water purer than spring or well water?

Other meats and fish may be pickled in brine, a concentrated solution of salt. Bacteria cannot live in salt; the water from their protoplasm diffuses out into the strong salt solution and, therefore, the bacteria are destroyed.

Food, especially meat, kept in a warm place begins to decay. That is, certain bacteria begin to develop in it and may produce poisons known as *ptomaines* (tō′mānz). Ptomaine poisoning often produces serious illness and even death. It is sensible not to eat any food that has even a suggestion of a bad odor or a bad taste.

SAFEGUARDING WATER

With your food, or whenever you are thirsty, you take a drink of water. You get it from a faucet, or a pump, or a fountain.

THE CASE OF "THE SAFE GLASS OF WATER"

How trustful you are! You know there are bacteria everywhere. You know many of them cause disease. You know a good many of these bacteria live in soil from which your drinking water comes. Nevertheless, you are not afraid of your family water supply, if you live on a farm; you have faith in your city supply, if you live in the city.

How is it that the glass of water is not laden with disease germs? We are going to follow a drink of water from its source in the clouds to its destination, your faucet or pump. Thus we shall see why water comes to you relatively free of germs.

GETTING WATER FROM A SPRING

One prospective glass of water fell as rain on a hillside near a farmer's house. It sank into the ground and became a part of the soil water. This water sank

farther down until at about 18 feet the soil was saturated. Somewhat below this point, the water was stopped by a solid layer of rock, or hardpan, which sloped toward the house. The water then moved down this underground slope to a deep stone-lined basin which the farmer had built.

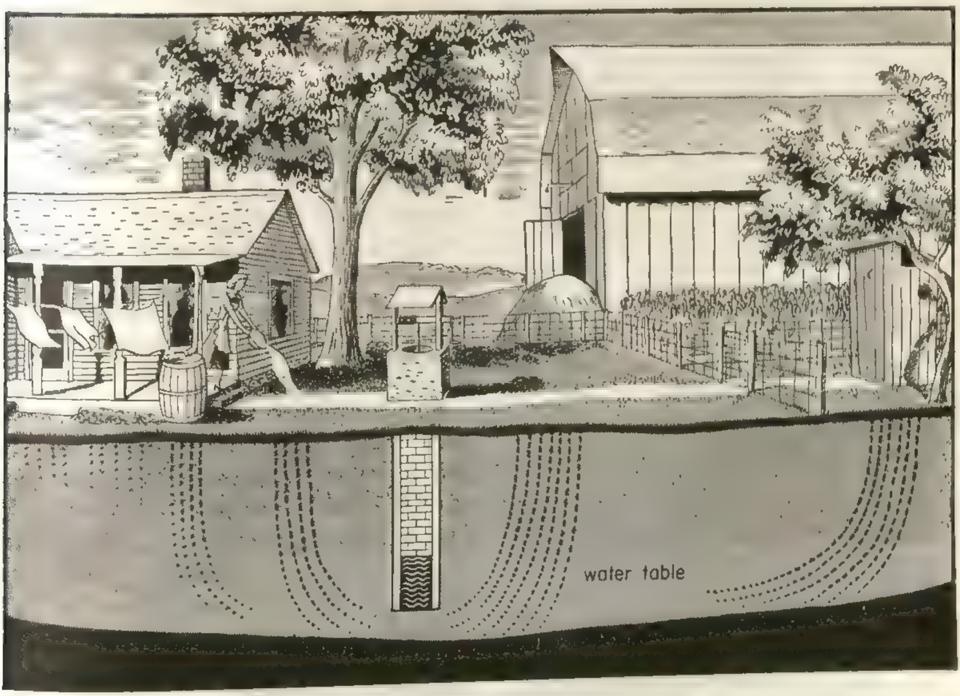
Here the water was trapped, so to speak. It filled the bottom of the deep basin and either flowed out of the spout or was pumped out. Thus the farmer got his water from a cool spring (Fig. 395).

AN ORDINARY WELL ON A NEW YORK FARM

As water sinks into soil it reaches a point where the soil particles hold as much water between them as is possible. We say then that the soil is saturated. The top of this saturated soil layer is called the *water table* (Fig. 396).

Let us take a look at the water table on a New York farm. The water table here is usually about 10 feet below the surface after a heavy rain, and about 16 feet from the surface in dry weather. The owner of the farm had dug a well about 22 feet deep, with walls of stone to keep the soil from falling in. Rain water seeps through the walls and through the bottom of the well. Of course, the water in the well usually stands at about the height of the water table (Fig. 396).

Only in severe droughts does the water table go below 16 feet. Then the farmer's well goes dry. Even if his well were dug far below the water table, he would be in trouble in a dry spell. He

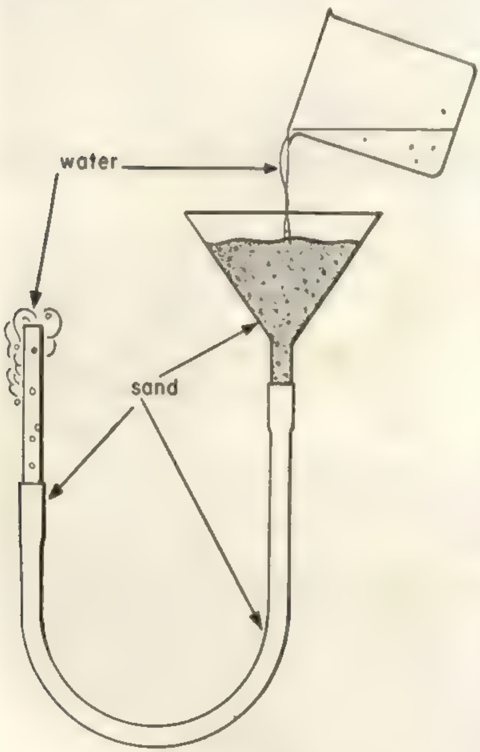


396 *Is this well in a safe place? Notice how seepage from the outhouse, the manure pile near the barn, and other places reaches the water table (light gray) that supplies the water to the well.*

still would have to depend upon rain water seeping through the soil. Unless there was a plentiful rain supply, he would need an artesian well or a driven well. A driven well is drilled very deep and may go down more than 100 feet.

ARTESIAN WELLS

To dig an artesian well, our New York farmer hired a well-drilling machine. With it he drilled down into a layer of porous sandstone 200 feet below the surface of his farm (Fig. 395). The rain water which came up in this artesian well may easily have come from many miles away, traveling along a layer of porous rock far below



397 *A model to illustrate the idea of an artesian well. The rubber tube represents the nonporous layer; the sand, the porous layer; the glass tube, the pipe which reaches the water in the porous layer.*

the surface of the ground. It could not escape for it was enveloped in this porous rock by solid rock layers (Fig. 395). When the solid rock and soil above it were pierced, the water gushed from the artesian well.

WATER SEEKS ITS OWN LEVEL

Why does the artesian well water come to the surface? Let us make a rough model of an artesian well to see the way it works. Take a large sized funnel like the one in Fig. 397 and fill it with sand. Attach it to 2 or 3 feet of rubber hose which has also been filled with sand. Fit a glass tube into the other end of the hose. The funnel with sand represents the porous rock at the surface of the soil and the rubber tubing with its sand represents the porous rock layer surrounded by nonporous rock. The glass represents the pipe from the hole drilled into the porous rock.

Hold the glass tube above the funnel and fill the funnel with water. Now lower the glass tube slowly till you see water in it. Compare the water level in the funnel with that in the tube. They are the same, aren't they? If you lower the tube below the water level in the funnel—over a sink, please—the water will flow from the tube. Water, you see, reaches its own level.

In our New York farmer's artesian well, the surface porous rock caught the water at a level higher than the opening which the farmer had drilled. Do you see that it is the height of the source of water which is partly responsible for the water flow in the artesian well? But the hard rock layers, which enclose the porous rock containing water, are also partly responsible for the pressure; for they permit the water to escape only at the place where the artesian well was driven. On

the basis of what you have learned here can you explain the equal level of the water in the tubes in Fig. 397?

PURE WATER ON THE FARM

Whether our water comes from springs, shallow wells, or artesian wells, we are interested in its safety for drinking purposes. In other words, is the water polluted with bacteria? If the well is carefully built, the water probably is safe to drink. The water as it seeps through soil and rock is usually freed from most bacteria and soil particles.

However, there is a danger. Suppose an outhouse or manure pile exists at a higher level than the spring or well (not an artesian or driven well). During rains, some of the sewage will seep into the soil water. Since this contaminated water is at a higher level than the well, there is danger that the bacteria in the sewage may get into the drinking water. Artesian wells or deep driven wells are usually safe from this danger because of the great depth of the rock or soil layer.

Since typhoid germs breed in water in which sewage is dumped, disposal of sewage is one of the most important functions of your community. In the city, sewage is either dumped far from the city limits or made harmless by chemical treatment. Garbage is removed and burned. On the farm, the individual farmer is responsible for safeguarding health. He must provide for the removal of sewage and garbage. Sewage needs to be disposed of far away from wells and the milk house (Fig. 396). As a matter of fact, it is good farm practice as well as good health practice, to place outhouses and manure piles (1) to one side of the source of drinking water, (2) below the source, and (3) at least 100 feet away from it. Where there are indoor toilets, the septic tank (which receives the sewage) should be placed at least 100 feet away from the water sources. At this distance, there is little danger that seepage from the sewage will reach the well water.

A farmer's well should yield water safe for drinking. Look at the picture of a well in Fig. 396. Can you see why the water in this well would be unsafe for drinking purposes? Does your family depend on a well? Is it a safe one?

SAFE WATER FOR THE MILLIONS

Getting water into the city faucets of New York or San Francisco is a great engineering accomplishment. Artesian wells could not begin to furnish enough water. As a matter of fact, New York City does not now have a water supply sufficient for its growing population. Engineers are at work trying to tap sources of water. The Delaware River and the Hudson River are being explored as possible sources.

Your glass of city water, therefore, may have come a long way. For instance, a New York City glass of water begins its travels in the Catskill Mountains 80 miles away. It joins its fellows in one of the large artificial lakes built by damming several rivers which have received water from many creeks. These creeks collect the rain water from a large area, called the *watershed.* The water finally runs into the Ashokan (ȧ shō'kăn) reservoir. The water in this reservoir alone could cover all of Manhattan to a depth of 25 to 30 feet. The large Ashokan reservoir is supplemented by other reservoirs such as the Croton and Kensico.

From the Ashokan reservoir, the water goes through an aqueduct. This aqueduct, which was started in 1905 and finished in 1917, runs 120 miles, up hill and down and under the Hud-

son River. It is 40 feet wide in certain places. At one point, it is 1,200 feet below the surface of the ground (Fig. 398).

What a strenuous journey for water to take from watershed to faucet! The source for New York City, 80 miles away in the Catskills, is so high that water will flow to the twentieth story of most buildings. However, tall buildings need to have their water pumped to the faucets in the upper stories.

San Francisco has water supply problems similar to those of New York. Both are surrounded by water—salt water. Should someone find a practical way of purifying huge amounts of sea water for drinking, large coastal cities like San Francisco would have their water supply problems solved. At the present time, San Francisco depends on a fast-flowing river high in the mountains. The river was dammed up to form a system of three reservoirs which supply San Francisco with water.

Both New York and San Francisco depend mainly on gravity to bring them water from their watersheds. Their sources of water are situated several hundred feet above the cities they supply.

For cities on the plains, such as St. Louis, Milwaukee, Chicago, and Cleveland, water has to be pumped day in and day out. Milwaukee takes its water from Lake Michigan; Buffalo, from Lake Erie; St. Louis, from its rivers. The cities which take their water from the Great Lakes have a problem. Sewage is emptied into these lakes. But after

398 *Nearly three-quarters of the water used by New York City's 8,000,000 people is carried to the various parts of the city through two tunnels. Like the one shown above, both tunnels are 17 feet in diameter and lie 200 to 800 feet below the ground. On a hot day the two tunnels carry about one billion gallons of water. Even so, water must be used carefully and not wasted. (Department of Water Supply, New York City)*

the water has been treated chemically, it is completely safe to drink.

How do cities treat their water supply to purify it and give you a safe glass of water?

PURIFYING A GLASS OF DIRTY WATER

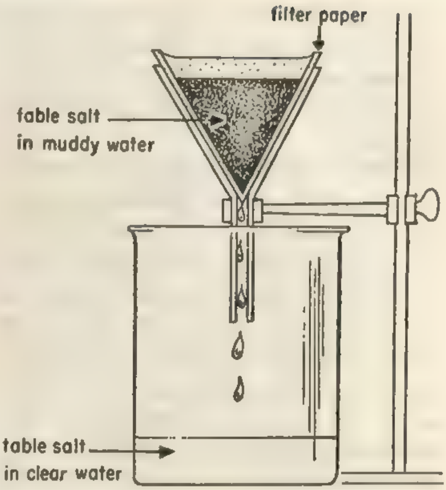
Suppose we were to dump some soil into a glass of water. You know that soil contains bacteria. How would you make that water fit to drink? You would filter it through a filter paper to get rid of soil particles. You would boil it thoroughly to kill the germs. But then it would have a flat taste. In boiling you have removed dissolved air which gives water its taste. Pour the water back and forth, from glass to glass to mix air with it. You will have *aerated* (ā′ĕr āt′ĕd) the water and restored its taste.

In a small way, you have gone through the processes by which a city gives you a safe, tasteful glass of water. But how are billions of glasses of water treated at once?

GETTING RID OF PARTICLES IN WATER

As the water stands in reservoirs, most of the particles (being heavier than water) settle to the bottom. Thus, the water in the reservoirs is fairly clean. To hasten the filtering, many cities send their water through settling basins where the water settles through filtration beds. In a filtering plant there are a large number of concrete filtration beds, each of which consists of layers of sand and gravel. Soil and other particles, even some living things, are caught in these beds. At the bottom of each bed there is a large pipe which leads to other large water pipes or mains.

You can make a model filtering bed by using a funnel with sand and gravel as in Fig. 399. Pour muddy water



399 *This drawing illustrates the idea of a filtering bed, showing that muddy water (containing insoluble particles) comes through clear. But, as the diagram shows, this method does not get rid of soluble minerals like salt. Other methods must be used to eliminate substances which have dissolved in water.*

through it and see how clear it is when it comes through the sand bed.

In some municipal settling basins, the particles suspended in water may be made to settle faster by the use of chemicals. Make a model settling basin, to see how one works. Take some alum and add it to limewater. You will notice that a white insoluble substance called aluminum hydroxide is produced. This substance settles quickly to the bottom.

In settling basins, alum is added to the water to make bacteria as well as particles settle quickly. The water in these basins appears to be very clear even before it is sent to the filter beds.

KILLING THE BACTERIA

Aeration is next in the process of purifying water for cities. The water

is sent up in sprays—up into sunlight and air which help in killing bacteria. Aeration restores the taste to water and helps remove odors. However, this is not enough.

While the water is still in the mains and before it reaches the faucet, chlorine gas is added. Yes, this is the poisonous gas you have heard about. But it is added in such small quantities as to kill bacteria and to do people no harm. A staff of skilled technicians makes daily tests of the water. If they notice an increase in bacteria, they increase the amount of chlorine.

RESULTS!

In these elaborate and careful ways, the water you drink is made safe. As a result, in most large cities, typhoid fever, a water-borne disease, is no longer a menace. In New York City only one person in every 200,000 died of typhoid fever in 1940, and this person did not get it from the city's water supply.

Your community is constantly trying to reduce disease. Look at the graph in Fig. 390. See how the number of deaths due to disease has been lowered. Part of this is the result of safeguarding food and water by the methods which have been described. Part of the new freedom from sickness is due to the education each one of you gets in keeping healthy.

CONTROLLING MODERN PLAGUES

The black plague in 1665 wiped out almost one-third of the entire population of London. Yet there are very few plagues in modern cities. What is the story behind this conquest of disease?

DISAPPEARING PLAGUES

In the modern community, health departments keep a never-ending watch for any increase in the rat population. Why watch rats? Rats carry the flea which in turn carries the bacterium which causes bubonic plague, the black death that terrorized our ancestors. Health inspectors constantly examine water-front areas, fumigate warehouses, and war on rats the year round.

Smallpox was once a plague which swept through whole populations. It killed and disfigured thousands even as late as the middle of the nineteenth century. Now vaccination against smallpox has been made so easy that in states requiring it almost every child has been vaccinated.

Your health department seeks to detect disease and stop it before it can spread. Have you ever had a Schick test? Early in your school days, this test for susceptibility to diphtheria may have been given to you and your schoolmates.

Many communities also test for tuberculosis by X-raying all children and their families. Have you had an X-ray test yet? It is an interesting experience and a good health practice. It is also one of the ways in which tuberculosis, the "white plague," may be detected.

One of our modern plagues is malaria. It undermines the health of three million people annually throughout the world. There was a time when localities as far north as New York and Ohio had many cases of malaria. The disease is now centered in warm climates. The centers of this plague are India, China, and other countries situated in tropical zones.

Cities and towns, especially in the South, drain swamps to stamp out the aëdes and anopheles mosquitoes which may carry yellow fever or malaria.

HOUSES MAY BECOME PRISONS—FOR HEALTH'S SAKE

You realize that in large cities and other areas where people live close together, the people themselves may spread diseases caused by germs. In this way, diphtheria and smallpox, for example, spread before methods of controlling them were discovered. In this way, measles and other diseases are still spread.

Nowadays, however, when someone becomes ill with a disease which may be transmitted by contact with people—such as measles, scarlet fever, or diphtheria—many communities quarantine the family. Not only the patient, but any member of the family who may spread the disease, must stay at home. Not everyone is likely to spread the disease; but the boards of health of towns and cities must treat all alike. At any rate, quarantine is useful; it keeps the disease from spreading to others. Next time you see a quarantine sign on a door, you will know that your community is safeguarding your health.

A GALLERY OF GREAT MEN

The health measures described here did not just happen. They are not accidents, but rather the result of hard, brilliant work by men and women of science from countries throughout the world. Great researchers have contributed to every health measure in your community and to every plague control. Here are a few of the very many to whom you owe a great debt.

Louis Pasteur (päs′tûr′), 1822–1895, a great French scientist, laid the foundation for the study of disease. His work led him to believe that most diseases were caused by germs. Other scientists then began to look for microorganisms as the cause of disease. Pasteur also discovered a preventive treatment for rabies, or hydrophobia, and the cause of anthrax, a disease of sheep.

Robert Koch (kôκ), 1843–1910, a German scientist, built on the work of Pasteur and discovered the tuberculosis bacillus. He tried unsuccessfully to find a cure for tuberculosis.

Joseph Lister (lĭs′tēr), 1827–1912. This Englishman applied Pasteur's work to keeping bacteria out of wounds. Before his time, even a minor wound could result in death. He was the first to use antiseptics in surgery.

Edward Jenner (jĕn′ẽr), 1749–1823, was an English scientist who introduced vaccination. He injected people with cowpox virus and thus made them immune to smallpox. However, it was not until the late nineteenth century that vaccination was accepted by the majority of people. Remember that at the time Jenner worked, bacteria or viruses were not known to cause disease.

Élie Metchnikoff (mĕch′nē kôf), 1845–1916, a Russian scientist, discovered that white blood cells engulf and destroy bacteria.

Sir Frederick Banting, 1891–1941, together with other scientists of Canada, discovered a method for preparing insulin from the pancreas of animals. In this way, he made it possible for diabetics to live a normal life.

Sir Alexander Fleming, 1881–   , was the British discoverer of the effect of the mold Penicillium on growth bacteria, who started scientists on the development of one of the great chemical cures of this century. Long before him, *Dr. Paul Ehrlich* of Germany used the first chemical cure, Salvarsan, to treat syphilis.

Science, as you can see, knows no national barriers. Men and women of all nationalities, all religions, and all races contribute to it.

A TEAM OF SCIENTISTS CONQUERS YELLOW FEVER

When we think of the men whose discoveries help to keep us healthy, we must not fail to remember that gallant group of men whose work laid the foundation for control of yellow fever throughout the world.

Dr. Walter Reed had been sent to Cuba to seek the cause of yellow fever. Where was the killer? The aëdes mosquito was suspected of carrying the disease. How was the proof obtained?

Dr. Reed called for volunteers. Privates Moran and Murphy, Dr. Agramonte, and Dr. Lazear responded among others. Some of these men were controls; they were kept in rooms free from mosquitoes. But others allowed mosquitoes to feed on their blood. The men who lived in screened cottages where the aëdes mosquito could not penetrate did not get yellow fever. Others who were exposed to certain of the mosquitoes which carried the disease were stricken with it.

Thus a group of courageous men proved that the mosquito carried yellow fever. Some were permanently disabled; one, Dr. Lazear, died of the fever.

These are some of the men who have contributed to your good health. Your debt stretches to them and to countless others who have worked and are working in laboratories throughout the world to control the diseases caused by microorganisms. They have worked against great odds, the ignorance and prejudice of people, the opposition of communities. They have often worked without the kind of appreciation benefactors of mankind should get. You can repay your debt by using the knowledge they have given you to protect yourself against disease, to live in good health. They desire no more. You can do no less.

GOING FURTHER

As you grow older, you will be faced with the questions: Shall I smoke? Shall I drink?

What decisions will you make on these personal problems which will affect your health?

1 *Effect of smoking.* Does smoking affect a person's health? Dr. Raymond Pearl of Johns Hopkins University gathered these facts which may help you come to a decision.

Approximately 66,000 nonsmokers out of every 100,000 aged 30 may expect to reach 60 years of age.

Approximately 62,000 moderate smokers (two to three cigarettes a day) out of every 100,000 aged 30 may expect to reach 60 years of age.

Approximately 46,000 heavy smokers out of every 100,000 aged 30 may expect to reach 60 years of age.

The facts suggest (in your notebook check those that are true, place an X before those which are false):

1. That heavy smokers may expect to reach the same age on the average as nonsmokers.
2. That moderate smoking is not damaging.
3. That the more a person smokes, the more chance he has to live to a ripe old age.
4. That the more a person smokes, the more likely he is to live a shorter life.

You may want to read more about tobacco and its serious effect on the body. Then send for the pamphlet *Tobacco and Health* by A. H. Steinhaus and F. M. Gunderman, Association Press, 347 Madison Ave., New York, N.Y., 1945.

2 *Effects of alcohol.* As you get on in years (let us say 5 to 10 years from now) you may also want to know the answer to this question: What effect does alcohol have upon a healthy body?

You should know the facts. Here are some gathered by a committee of scien-

tists and published in a book called *Alcohol Explored* by Dr. H. W. Haggard and Dr. E. M. Jellinek, Doubleday Doran & Co., New York, N.Y., 1942.

1. About one-fifth of all deaths in traffic accidents are caused by drunken drivers or pedestrians.

2. With .003 per cent alcohol in the blood (3 drops to 100,000 drops of blood), unconsciousness results. Six drops per 1,000 drops of blood may cause death.

3. Constant and regular drinking of alcoholic beverages may result in a disease called alcoholism. This disease is dangerous to life and to mental health.

4. However, there is some evidence that moderate drinkers live as long as non-drinkers do.

What will your decision be? Why? Write an essay for your science or English class, or for your newspaper on the subject, "To drink or not to drink."

3 *Words are ideas.* Can you use these words in sentences which will give their meaning? Use the glossary.

antibody	artesian well
antitoxin	water table
filtration bed	trichina
vaccination	aeration
hydrophobia	quarantine
ptomaine	anopheles
alcoholism	insulin
cancer	degenerative diseases

4 *Put on your thinking cap.*

1. In 1941 the typhoid fever death rate in the United States was about 1 per 100,000. This is to be compared with 35 per 100,000 in 1900. This means that about one out of every 100,000 people, or about 1,400 people, still die each year from typhoid fever. What needs to be done to eliminate these deaths?

2. In country X, the death rate from a certain contagious disease is regularly 75 to 90 per 100,000. This is quite high. What are some steps you would take if you were health commissioner for the country?

5 *Test yourself.* In your notebook complete the following statements with a word or phrase. Do not mark this book.

1. The germs in drinking water may be destroyed by introducing the chemical ...... into water pipes.

2. The theory that diseases are caused by germs was proposed by ....

3. The anopheles mosquito carries germs of the disease ....

4. Trichina is found in ....

5. Milk is pasteurized at a temperature considerably below the boiling point of ....

6. Wherever there are evidences of stream pollution from human wastes, there is danger of several diseases. A common one is ....

7. The X-ray test is a means of detecting infection by the ...... germ.

8. Oil floating on the top of water where mosquitoes breed will kill the ....

9. ...... people against smallpox is the best way of preventing its spread.

10. The discoverer of the cause of tuberculosis was ....

CHAPTER 34

SAFETY FIRST

Before you have finished reading this page, a man, woman, or child will die in the United States. Not from disease or warfare, but from *carelessness* on somebody's part. In the few seconds in which you were reading these three sentences, some man, woman, or child was injured by an accident. Again, *carelessness.*

In April 1945, the United States Army, Navy, and Marine forces invaded Okinawa in the Pacific. The Japanese fought stubbornly; 82 days of fierce fighting were needed to subdue them. The price paid for that victory was 43,376 casualties, of which about 5,000 were deaths.

But in the same 82 days back home in a United States untouched by bomb or bullet, 22,000 people died. From disease? No, these people died in accidents. During this period, 2,300,000 people suffered accidental injuries. Yet many of these accidents could have been prevented.

Automobile accidents alone killed 28,500 people in 1945. This figure means that approximately three people died every hour. However, automobiles are responsible for only about one-third of the accidental deaths in the United States each year.

100,000 DEATHS A YEAR

Suppose you saw this headline in a newspaper:

105,000 KILLED

Would you suppose that a new atomic bomb had exploded? Not at all. This was the number of Americans killed in 1937 by accidents. Each year in the period from 1935 to 1948, about 100,000 men, women, and children were killed in accidents in the street, at work, or at home. Give this your attention: during the same period about 10,000,000 were injured each year. In more recent years, the accident rate has been lowered somewhat. In 1943, for instance, 94,500 died in accidents while 9,700,000 were injured.

In previous chapters, you learned enough about disease to co-operate in disease prevention. But you can see that accidents today take a terrible toll in deaths and injuries. The responsibility for preventing accidents is both the community's and the individual's.

There are two parts to the accident problem:

1. How can accidents be prevented?
2. How can accidental injuries be treated to prevent their becoming more serious?

PREVENTING ACCIDENTS

Records kept by the National Safety Council, an organization devoted to promoting safety in the United States, show that most accidents occur at home. Yet this is the place where every one of us can help prevent accidents.

YOUR PART IN ACCIDENT PREVENTION AT HOME

You can check your home for six main danger spots. For each "yes," give yourself plus 10, for each "no," minus 10. Keep a careful record of your score.

1. *The hallways.* Are there rubber mats under loose carpets to prevent slipping? Are toys, especially marbles or toys with wheels, put away where no one will trip over them? Are hallways and stairways well lighted? Falls are the cause of most injuries in the home.

2. *The bedrooms.* Is there a light near the bed in each bedroom which may be put on in case of need?

3. *The bathroom.* Has the bathtub a handgrasp? If not, has it a small rubber mat on which one may step? Wet slippery bathtubs are one of the major causes of home accidents.

Examine the medicine cabinet. Is every bottle properly labeled? Is your medicine cabinet well stocked? Is it out of the reach of young children? Is there a place for the disposal of razor blades?

4. *The electric wiring.* Are electric wires safely covered? Many babies and small children are killed each year by defective wiring. *Do not touch frayed wires unless the plug is out of the socket.*

5. *Storage space.* Is everything stored in such a way that heavy objects will not fall on your head? Are stored things easy to get at? Are the heavier things on the floor? Are the lighter ones on the upper shelves?

6. *Nightly checkup.* Before you go to bed, do you check these danger spots?

Is the gas stove turned off?

Are outside doors closed and locked?

Is the window arranged so that you are protected from rain or snow?

If you were to get out of bed in the dark, would you trip over something near the bed? If so, remove it.

A score less than perfect means that your home is dangerous to the health and safety of you and your family. Remember, every year about 20,000 people under 20 years of age die accidental deaths.

YOUR PART IN ACCIDENT PREVENTION IN THE STREET

Give yourself 10 points for every "yes," and minus 10 for every "no." You are living dangerously and stupidly if you get a score lower than 90.

1. Do you play in a playground rather than in a street?
2. Do you wear sneakers rather than leather-soled shoes when you play on cement or grass?
3. Do you wear boots or rubbers when you walk on ice or snow?
4. Do you cross the street at safe points and only with the traffic light?
5. If you wear glasses, do you resist the temptation to leave them at home, or in your pocket? (If you do, you may not see danger in time to react quickly.)
6. If you wear glasses, are they sufficiently protected by a guard when you play basketball?

7. Do you resist the desire to climb over barbed wire?

8. Do you keep on the proper side of the road when cycling or walking?

9. Do you report injuries to your parents or teachers?

YOUR PART IN PREVENTING ACCIDENTS AT SCHOOL

In which of these columns are you, the wrong or the right?

Wrong	Right
1 Running in the halls and leaping down or up stairs.	1 Considering others while walking in halls or on stairs.
2 Failing to report a broken chair.	2 Reporting any broken furniture to prevent injury to yourself and others.
3 Making yourself a nuisance during fire drills.	3 Co-operating to save lives, by getting out of the building as rapidly as possible. No talking; no jostling.
4 Playing games on wood or cement floors without sneakers.	4 Co-operating by wearing proper shoes and clothing on the gymnasium floor.
5 Wearing glasses without a guard during a basketball or football game.	5 Wearing a guard over glasses.

PREVENTING ACCIDENTS AND INJURIES ON HIKES

A hike is ordinarily a joyful, healthful undertaking, but not if it results in an accident or injury. If your scores on the tests so far have been high you already are partly protected from accident and injury. However, on a hike you may meet situations generally not found in the street, school, or home. For instance, there is poison ivy; there are loose rocks or vines which may trip you; campfires which may burn you or cause forest fires. Of course, using your common sense will help keep you safe and sound. You should not go for a full day's hike into an unknown section of the country unless you have some first-aid equipment in your knapsack. What should you take along?

FIRST AID TILL THE DOCTOR COMES

Your first-aid equipment will come from a well-stocked medicine cabinet at home.

Check your medicine cabinet for these items.

1. A small pair of scissors and tweezers.
2. A box of sterile gauze pads.
3. A box of band-aids.
4. Adhesive tape (2 inch size).
5. Sterile bandages—3 inch, 2 inch, 1 inch.
6. Two triangular bandages.
7. Iodine—2 per cent solution, not 7 per cent.
8. Spirits of ammonia.
9. Burn ointment—tannic acid jelly.
10. Rubbing alcohol.
11. Boric acid solution for washing the eyes; an eyecup for each member of the family.
12. Sunburn ointment.
13. Epsom salts.
14. Calamine lotion for poison ivy.
15. A clinical or fever thermometer.

Items 1 through 9 should be in your knapsack when you go on any hike. Now you are prepared for most emer-

gencies. What may happen? Almost anything, you say. Generally, few accidents happen to sensible people. Should one occur, you will want to do two things:

1. Give first aid.
2. If the accident appears serious, you will want to call a doctor.

In any case, report any accident or injury, small or large, to your hike leader or to your parents when you get home. First aid means giving aid at the scene of the accident until an expert can look at the injury and give treatment. Learning to give first aid is not difficult—your first step should be to read the following.

FIRST AID FOR CUTS AND BRUISES

Get a friend and practice first aid. Assume he has a small cut on the middle finger. Don't touch the cut with your finger. Your finger is not clean; it has germs on it. It is not necessary to apply iodine. Wash the cut with soap and water. Bandage it as follows: If it is a small cut about $\frac{1}{4}$ of an inch, just put on a band-aid. Be sure the band-aid is loose so that circulation is not cut off.

If it is a large cut, perhaps one inch or more, take one of the sterile pads and place it on the cut. Be sure not to touch the part of the pad which will touch the finger. Now wrap the finger with a two-inch bandage loosely so as not to interfere with circulation of blood, but not so loosely that the bandage will slip off. Tie the bandage or use some adhesive tape.

FIRST AID FOR BLEEDING

Sometimes a cut may be deep enough to injure a surface artery. The blood may come out in small spurts. If such bleeding occurs, call the doctor at once. Until the doctor comes, the bleeding should be stopped by applying a sterile gauze pad to the wound and pressing it down tightly enough to stop the bleeding. Hold this till the doctor comes.

If there is bleeding from a large artery, let us say at the wrist, pressure should be applied either directly on the cut as described above or at the pressure point on the arm. But if the bleeding cannot be stopped by pressure from the fingers, a tourniquet may be applied. This should be done only if there is no other way to stop the bleeding. You can see that a tourniquet cuts off the supply of blood to the body parts below it. Therefore it should be released every few minutes. However, you will find that in most cases where the cut is not large, pressure applied with the fingers on a pad of sterile gauze placed on the cut is sufficient to stop the flow.

Bleeding from a vein is not so difficult to stop as bleeding from an artery. First, the blood does not spurt, it flows evenly. Second, it flows more slowly. For first aid to an injured limb, pressure may be applied with the fingers on a pad of sterile gauze on the cut. Unlike blood in the arteries, which is coming from the heart, blood in the veins is returning to the heart. Therefore, the source of blood in the veins is below the cut. Pressure on the cut will halt the flow of blood long enough for you to get to the doctor. If the trip is long, pressure on the cut should be gentle but firm. But get to a doctor as soon as you can.

Everyone should know how to control the common nosebleed. If your nose starts to bleed, merely put your head back over the back of a chair and hold a handkerchief to the bleeding nostril. Breathe with the other one. Do this for about five minutes to allow the blood to clot and then hold your head erect. If more blood appears on

your handkerchief, lean back for five more minutes. If you have frequent nosebleeds, you should see a doctor.

FIRST AID FOR BURNS

Suppose you have been hiking for hours. You are very hungry. You grab a hot frying pan from the fire. You burn yourself. If your skin is merely reddened, you have a first degree burn.

Don't use iodine. Don't use oil or grease, which may make the injury worse. Use a good burn ointment like tannic acid jelly and then bandage as you would for a large cut.

In a severe burn, the skin may be charred. Do not treat it. Make a very loose bandage over the burn with sterile gauze and get the person to a doctor at once. The tissues underneath the skin have been injured.

FIRST AID FOR SUNBURN

Every summer you have a long vacation. On the very first day you probably rush off to swim. Then you relax in the bright sunlight. You come home with a day's sunburn. It may be a first degree or even a second degree burn. It can be quite painful. If the skin is broken you may get an infection. All you can do is put on burn ointment such as tannic acid jelly or some sunburn lotion. Do this immediately.

In order to tan, it is not necessary to get a painful and even dangerous sunburn. Start out at the beginning of the summer with the idea that there are many days at the beach or lake. The first time you should expose yourself 10 or 15 minutes. The next day, 20 minutes, the next day a little longer, and so on. You will tan gradually, handsomely, and painlessly.

FIRST AID FOR POISON IVY

On some of your hikes, you may meet with poison ivy or poison oak, thought by some to be a variety of poison ivy. These plants have an oily substance in their leaves, stem, and roots which causes the skin to itch and blister.

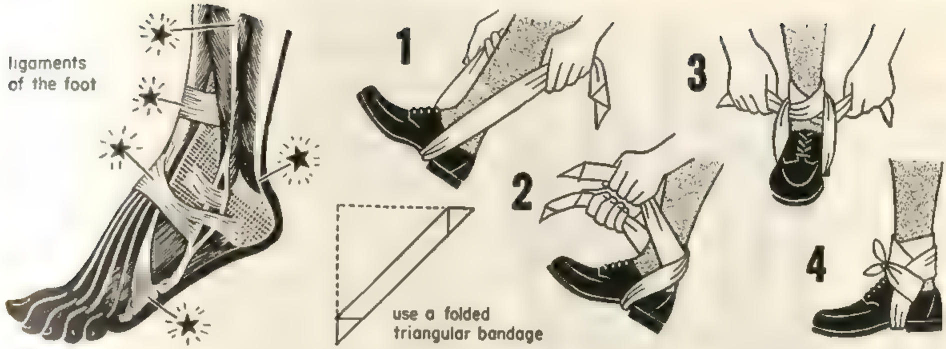
Study Fig. 400 closely. These are drawings of the leaves of common plants, two of which are poisonous. Try to impress them in your memory so that you will recognize them in the field. You ought to know that:

1. Poison ivy is a vine or shrub. Poison oak is generally a shrub.

2. Their leaves may be all colors from light green to tan or red. They may be dull or shiny.

3. The only sure way of identifying poison ivy or poison oak is to note that each of their leaves is composed of three

400 *How do you distinguish poison ivy and poison oak from other vines? Notice the long stem of the middle leaflet in both poisonous plants.*



401 *How to bind up a sprain while you are on a hike. In a sprain, the ligaments are pulled.*

leaflets, of which the middle one has a longer stemlike structure than the two side ones (Fig. 400).

Now look again at the drawings and test yourself. Can you identify the poison ivy and poison oak leaves?

If you think you have been exposed to poison ivy, wash all exposed parts of your skin with warm water and strong laundry soap. This will reduce the danger of your being affected by poison ivy. The day after, put calamine lotion on any itching part. Do not scratch. If a bad case of poison ivy does develop, see a doctor.

FIRST AID FOR SPRAINS

You are now equipped to handle cuts, burns, and poison ivy, the three hazards of the hike. But if you are at all venturesome, you soon will find yourself climbing a hillside, or scrambling over rocks and boulders. In the first place, be careful. Be sure of your footing at each step. Unsure footing may result in a fall and your ankle joints may be pulled too far apart. The tendons which hold muscle to bone, or the ligaments which hold bone to bone may be pulled (Fig. 401). This is what we call a sprain. Tendons and ligaments become sore and swollen and very painful to movement and touch.

Naturally, you should keep off the sprained ankle till the doctor has told you that no bones are broken. If you should get a sprain, bandage it tightly (Fig. 401). At home, cold cloths applied to the swollen part will help relieve the pain. However, if the sprain does not feel better in the morning, see a doctor. He may have to take an X ray to be sure that no bones are broken.

FIRST AID FOR THE DISLOCATION

Sometimes the bones are pulled so far apart that they do not take their normal position (Fig. 402). We say then that they are dislocated, or out of joint.

You may be able to treat a dislocation of a finger. But do so only if you cannot reach a doctor easily. Pull steadily but gently on the finger, and press the joint in place. When you get home, see your doctor. Don't treat dislocations of the arm or leg. If someone dislocates a bone, do not touch the injured part. Call your teacher, or a policeman, or hail a car to take you and the injured person to a doctor or hospital.

FIRST AID FOR BROKEN BONES

The bones of boys and girls are fairly elastic and not easily broken. However,

402 *A dislocation. With care the joint may be pulled into place, but it is best to leave this to the doctor.*

if one of your friends breaks a bone, what will you do? If you are near a doctor, call him at once. It is better to have the doctor come to the scene than to attempt to move an injured person. The injury may become more serious if the person is moved.

But if you are far away from a doctor and must take your friend to him, then you must splint the arm or leg.

Fig. 403 shows you how to splint an arm. (Don't splint a fractured bone which has broken through the skin. In such a case, a doctor *must* be brought to the scene. Go out to the road and hail a car. Then get to a phone and call a doctor.) Flat strips of wood or thick newspaper may be used as splints. Be sure to pad the injured part with handkerchiefs or any cloth you may have. Then tie a cloth bandage around the splints. If the person is unable to walk, a simple stretcher may be made with two long limbs cut from trees. Two or three jackets are buttoned and tied around the branches. The injured person is placed carefully on the stretcher and carried to the nearest road.

LIVE AND LET LIVE

On a hike, you may meet harmful animals. A good rule to follow, unless you are a specialist in collecting animals, is to keep away from spiders, wasps, and snakes. Most snakes are harmless and will try to escape from larger animals. Some snakes, like the rattlesnake, copperhead, and the water moccasin, are poisonous. You should, however, be able to recognize the head of a poisonous snake. You need not get close to a snake to do this. From a short distance, you can see the triangular head with pits on both sides of it.

If you should be bitten by a snake, tie a tourniquet between the wound and the heart. Keep as quiet as possible while someone goes for a doctor at once. Remember that pressure from a tourniquet should be released every few minutes.

FIRST AID FOR FAINTING

Have you ever seen a person faint? He becomes pale and slumps to the ground. He is pale because blood has left his head. He falls because his brain (lacking sufficient oxygen) is no longer in control of his muscles. The first job is to get the blood back to the head quickly.

The best thing to do is to place the person on his back with his head lower than the rest of his body. If you have spirits of ammonia with you, wet a

handkerchief with some of it and place it near his nose. Don't dash cold water on the patient. Don't move the patient about. The main thing to do is to get the blood back to his head. A person who has fainted generally revives quickly. If he does not, call a doctor at once. When he does recover, do not allow him to get up. He should rest for five to ten minutes at least. He should be kept warm by means of blankets or extra coats.

If you feel faint, the best thing to do is to lie down. If you are sitting, you can place your head between your knees. If you are in the street, pretend to tie your shoelace. The blood will flow back to the head. In any case, no matter what the cause of the faint may be—hunger, excitement, fright, or injury, or even fatigue—check with your doctor when you feel better.

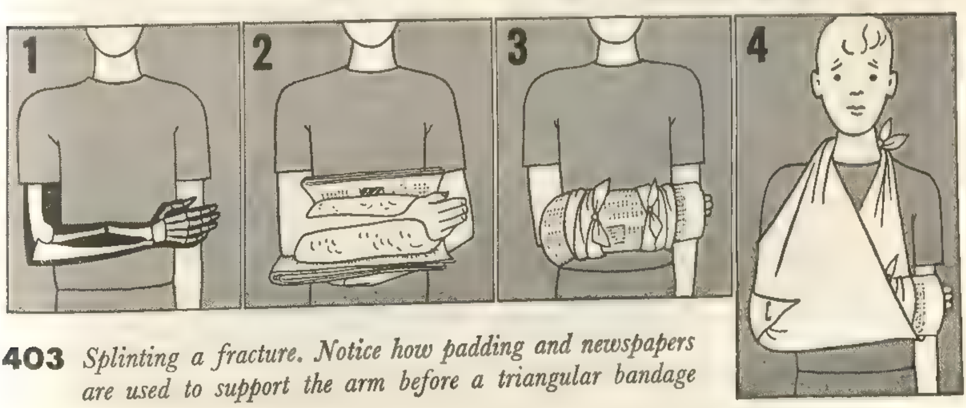
Any injury may be accompanied by fainting or shock. In shock, the blood leaves the head and limbs (as in fainting) and collects in the large blood vessels of the abdomen. Recovery from shock takes longer than from fainting. A person in shock should be treated exactly as in fainting with the addition that he should be permitted to rest until a doctor arrives. You should not try to distinguish between faint and shock since only an expert can tell the difference between them. Be on the safe side. Keep the person in faint or shock quiet, warm, and in a reclining position till recovery is apparent. Recovery will be on its way when color returns to the person's pale face, when cold sweat disappears, and when his cold clammy hands are warm again.

FIRST AID FOR SUFFOCATION

You will need to practice with a friend after you have read how to give first aid for suffocation. Both of you will want to practice artificial respiration. Why artificial respiration? In suffocation, a person suffers from lack of oxygen and may not be able to breathe. Therefore, the job of first aid is to start respiration again.

People may suffocate in many situations. Drowning is one of them. Swimming is not a dangerous sport unless the swimmer forgets to be sensible. For instance, swimming immediately after a meal is dangerous. Cramps of the stomach muscles may occur. A swim beyond the safety zone (in deep water) may be exciting if you are a good swimmer, but it invites drowning if you are a beginner.

No one should swim in deep water alone. It is wise to keep away from



403 *Splinting a fracture. Notice how padding and newspapers are used to support the arm before a triangular bandage is used.*

rocky ledges or steep beaches if you are in ocean water. The heavy currents near such places have been known to draw even powerful swimmers under the incoming waves.

Another cause of suffocation is carbon monoxide poisoning. Every now and then newspapers tell of a person found dead in his automobile in the garage with the motor running and all doors closed. The odorless gas, carbon monoxide, produced by the motor fills the garage. When it is breathed into the body, it goes into the blood stream from the lungs. Soon the blood is so full of carbon monoxide that it cannot carry enough oxygen to keep the body cells alive.

Suffocation may also occur when a person breathes too much illuminating gas, which also contains carbon monoxide.

In any case of suffocation, you should immediately send for a doctor. If your local police or fire department has a pulmotor, call for that first. A pulmotor is a machine designed to force air in and out of the lungs. Meanwhile, it is up to you to give first aid and try to revive the victim by artificial respiration. Practice with your friend under the supervision of your teacher. Place him in the position shown in Fig. 404. Now kneel over him and place both your hands on his lower ribs (Fig. 404). Your little finger should lie on his lower rib.

Now press firmly downward and forward to the slow count of 1 – 2 – 3 – 4 (about one per second). This will force air out of the lungs. At four, sit back quickly. Remove your hands just as quickly. Count 1 – 2 – 3 – 4. Air will rush into the lungs. Repeat this over and over.

Now it is your turn to lie down. Let your friend learn.

In actual cases, artificial respiration has been known to revive the victim after many hours when it seemed as if he had stopped breathing. Artificial respiration should be kept up till the victim breathes normally. In any case, he should be kept at rest, and kept warm by wrapping in blankets or coats during first aid and after.

A LAST WORD

Accidents happen to the best of us. But you can avoid many of them if you obey the rules of safety. A good many important pieces of advice are listed in this chapter. If an accident does occur, you can keep it a minor one by sensible first aid until a doctor arrives.

You can do a great deal to prevent accidents. Your friends and your family are depending on you, just as you are depending on them.

404 *The position to be taken in artificial respiration. On the down thrust air leaves the body, as shown by the narrow arrow. On the release, air enters the body.*

GOING FURTHER

1 *Preventing accidents.* Organize a Health Action Club to prevent accidents. Use the questions in this chapter to prepare a questionnaire to be given to all the members of your school.

2 *Essay contest.* Plan an essay contest on "Accident—Public Enemy No. 1." With the approval of your school, organize a board of citizens, teachers, and students to read the essays and award prizes. Perhaps the prize-winning essay can be published in your local newspaper.

3 *Check your home.* Have you checked your home for "danger spots"? If not, then do so at once.

4 *Traffic Patrol.* If you go to school in a large city, are you a member of the Traffic Patrol? This Patrol is stationed on street intersections. Its job is to stop automobiles while school boys and girls pass.

5 *Adding to your library.* Every home should have a copy of:

1. *Accident Facts* published by The National Safety Council, 1946 edition.
2. *First Aid Textbook*, American Red Cross, Blakiston, Philadelphia, 1945.

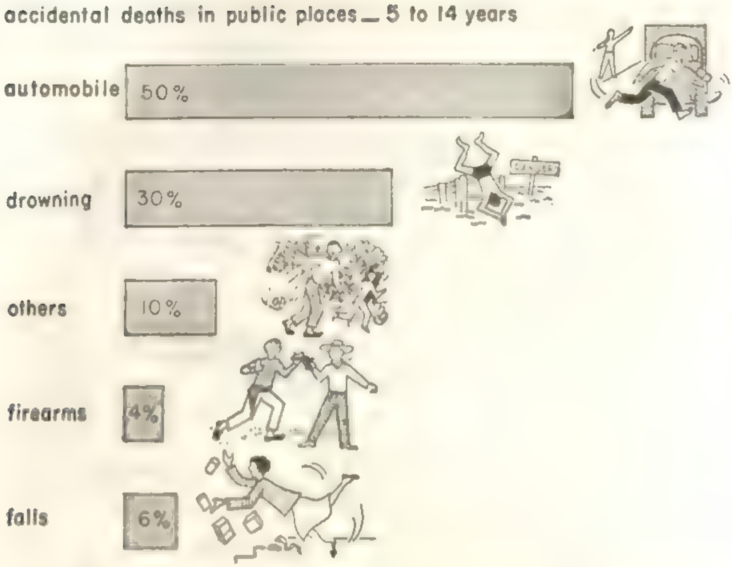
6 *Put on your thinking cap.*

Study these graphs (Fig. 405) summarizing the principal types of deaths caused by home accidents. They were prepared from facts gathered by the National Safety Council.

Name the cause of the greatest number of accidents occurring to people in the age groups below.

1. 0–4 years ......
2. 5–14 years ......
3. 15–24 years ......
4. 25–44 years ......
5. 45–64 years ......
6. 65 years and over ......

405 *Here you have a summary of the causes of accidental deaths in the home in the year 1946. What are the major causes of accidental deaths in your age group? (From "Accidental Facts, 1948," published by the National Safety Council, Inc.)*



406

Here is a summary of accidental deaths in public places for a recent year in the 5–14 age group. What is the major cause? (National Safety Council)

7 *Test yourself.* In your notebook complete the following statements with a word or phrase. Do not mark this book.

1. Bleeding from a cut blood vessel may be stopped by applying pressure to the ....
2. When a person faints a good way to help him is to ....
3. The most common cause of accidents in homes is ....
4. The first thing to do to a simple open wound is ......
5. If blood flows from a wound in spurts, an ...... has been cut.

8 *Words are ideas.* Can you use these words in sentences that will give their meaning? Use the glossary.

pressure point	first degree burn
artificial respiration	dislocation
sprain	splint

GLOSSARY

In this glossary, you will find the terms that are repeatedly useful in the study of science. Many have found their way into daily use.

This glossary, like any dictionary, is a tool to be used when you want to find a brief definition of a term. If you want to find out more about the word look it up in the index. There you will find reference to the page where the term was introduced and discussed fully.

If you once learn to use this glossary and any other word list as real tools, you will have gotten a skill that will be useful to you all your life.

acoustics (ȧ ko͞os′tĭks): the science dealing with the study of sound

acquired trait: a characteristic which is not inherited but is developed during the life of a plant or an animal

adaptation (ăd′ăp tā′shŭn): having suitable body structures and body activities to live in a certain environment

adult (ȧ dŭlt′): an animal which has attained full size

aëdes (ā ē′dēz): a mosquito that transmits the virus of yellow fever

aerated (ā′ẽr āt′ĕd): supplied or charged with air

aileron (ā′lẽr ŏn): a flap set in the edge of airplane wings to control the course of the plane

air conditioning: a system of treating air in buildings to regulate temperature and humidity, and to remove dust

airfoil: the cross section of an airplane wing

air mass: a large body of air having, level for level, the same temperature, pressure, and humidity

air sac: a thin-walled microscopic bag found in the lung through the lining of which oxygen, water vapor, and carbon dioxide diffuse normally

albino (ăl bī′nō): an animal or a plant which has no pigment or color

alcoholism: a diseased condition caused by long-continued excessive use of alcoholic beverages

alizarin (ȧ lĭz′ȧ rĭn): a dye made from coal tar

alloy (ă loi′): a substance composed of two or more metals; for example, bronze

alternating current: an electric current that reverses its direction in regular cycles

altimeter (ăl tĭm′ė tẽr): an instrument used to measure height above the earth's surface

aluminum (ȧ lū′mĭ nŭm): a bluish, silvery-white metallic element, light in weight

americium (ăm′ẽr ĭsh′ĭ ŭm): one of four new elements made by man

ammeter (ăm′mē′tẽr): an instrument for measuring the strength of electric current in amperes

amoeba (ȧ mē′bȧ): a single-celled animal common in ponds

ampere (ăm′pēr): the amount of electrons that pass a given point in an electric conductor (for example, a wire) in one second; the unit for measuring the strength of an electric current

amphibian (ăm fĭb′ĭ ăn): one of a class of vertebrates, including frogs and toads, that pass through a stage in which they live in water and have gills; later when these vertebrates move to the land the gills are replaced by lungs

amplitude (ăm′plĭ tūd): refers to the extent of the movement of a vibrating object and to the height of the wave produced thereby or by an oscillating electric current

anemia (ȧ nē′mĭ ȧ): a disease characterized by a decreased amount of hemoglobin in the red blood cells or a decreased number of red corpuscles or both

anemometer (ăn′ė mŏm′ė tẽr): an instrument for measuring the force or speed of the wind

aneroid (ăn′ẽr oid): a type of barometer which does not use air or any other liquid; the metal can in which there is a partial vacuum reacting to changes in pressure

anesthetic (ăn′ĕs thĕt′ĭk): a substance which stops the flow of impulses through nerve cells, thus halting the feeling of pain

angle of incidence: the angle between a ray of light and a line perpendicular to the surface that the light strikes

angle of reflection: the angle that a ray of reflected light makes with a line perpendicular to the surface at the point of reflection

aniline (ăn′ĭ lĭn): a coal-tar compound used in making dyes

annular (ăn′ū lẽr) **eclipse**: an eclipse in which a ring of the sun appears around the black disk of the moon

anopheles (ȧ nŏf′ĕ lēz): a mosquito that transmits the malarial parasite to man

antenna (ăn tĕn′ȧ): a conductor consisting of a wire or wires for transmitting or receiving electromagnetic waves (also called an aerial)

anther (ăn′thẽr): in seed plants, the part of the stamen which produces pollen

anthracite (ăn′thrȧ sīt) **coal:** a hard natural coal, mostly pure carbon, that burns with little ash

antibody (ăn′tĭ bŏd′ĭ): a substance found in the body which helps destroy bacteria

antiseptic (ăn′tĭ sĕp′tĭk): a substance tending to arrest the growth of bacteria

antitoxin (ăn′tĭ tŏk′sĭn): any substance in the body that neutralizes specific poisons (toxins) such as those produced by bacteria

aorta (ā ôr′tȧ): the great artery which carries the blood from the heart to all the body except the lungs

aphid (ā′fĭd): a tiny insect which sucks juices from plants

archeologist (är′kē ŏl′ō jĭst): a specialist in the study of art and customs of ancient peoples

argon (är′gŏn): a colorless, odorless, gaseous element occurring in the air

armature (är′mȧ tūr): a piece of metal or a coil of wire that moves back and forth or rotates in a magnetic field

artery (är′tẽr ĭ): one of the blood vessels that carry blood away from the heart

artesian (är tē′zhăn) **well:** a well drilled through rock layers from which water flows upward under pressure

arthritis (är thrī′tĭs): inflammation of the joints

asbestos (ăs bĕs′tŏs): a fibrous, fireproof substance

ascorbic (ā skôr′bĭk) **acid:** vitamin C, which prevents scurvy

asexual (ā sĕk′shŏŏ ăl) **reproduction:** producing offspring as a result of the division of one parent

asteroid (ăs′tẽr oid): one of a group of small planets between Mars and Jupiter of which about 1,500 have been listed; estimated number runs to 30,000 or more

astronomer (ăs trŏn′ō mẽr): one versed in the science of the heavenly bodies

Atabrine (ăt′ȧ brĭn): a drug used to combat malaria

atmosphere (ăt′mŏs fēr): the whole mass of air surrounding the earth; the gaseous envelope of any heavenly body

atom (ăt′ŭm): the smallest particle of an element that has the properties of that element

atomic bomb: a bomb whose explosive force comes from a chain reaction based upon nuclear fission in uranium 235 or in plutonium

atomic energy: energy produced by the changing of matter to energy (see **atomic fission**)

atomic fission (fĭsh′ŭn): the breaking down of an atom, especially its nucleus, into two or more parts with a great release of energy

atomic pile: a mass of uranium rods embedded in pure carbon that produces a chain reaction and releases atomic energy

atomic weight: the weight of an atom of any element compared with the weight of an atom of oxygen which is set at 16.000; Dalton used the weight of hydrogen (1) as a base

audiometer (ô′dĭ ŏm′ē tẽr): an instrument for measuring the power of hearing

auricle (ô′rĭ k′l): a chamber of the heart that receives blood from the veins

average: a general type; sometimes the middle between the extremes of a curve of normal distribution

axis (ăk′sĭs): an imaginary line through the earth's poles

bacillus (bȧ sĭl′ŭs): a rod-shaped bacterium

bacteria (băk tēr′ĭ ȧ): a group of widely distributed single-celled plants, some helpful, others harmful

Bailey's beads: beadlike lights around the dark edge of the moon which last for only an instant immediately before and after a total eclipse of the sun

bakelite (bā′kĕ līt): a synthetic substance that can be molded or shaped

balance in nature: the interdependence of all plants and animals with their environment

balanced diet: a plan of meals which includes in proper amounts all the nutrients required for good health

ballast (băl′ăst) **tanks:** airtight compartments in a submarine

barograph (băr′ō grăf): an instrument which measures changes in air pressure and records them on a graph

barometer (bȧ rŏm′ē tẽr): an instrument for measuring air pressure

bauxite (bôks′īt): a common ore of aluminum

Beaufort (bō′fẽrt) **scale:** a system of estimating wind speeds based upon the effect produced; originated by Admiral Beaufort of the British navy

beriberi (bĕr′ĭ bĕr′ĭ): a disease caused by a diet lacking vitamin B_1 (thiamine)

Bessemer (bĕs′ĕ mẽr) **Converter:** the vessel used in the process of making steel from cast iron by burning out carbon and other impurities from the cast iron by a blast of heated air

biologic production: production of food, forest products, medicines, etc., by living organisms

biologist (bī ŏl′ō jĭst): one who studies living things

bituminous (bĭ tū′mĭ nŭs) **coal:** a soft coal containing a number of inflammable substances including asphalt, tar, and naphtha

block and tackle: a set of two pulleys, one movable, one fixed, connected by rope and used for lifting or drawing heavy weights

blood: the fluid (commonly red in vertebrates) which circulates in the heart and other blood vessels
brain: the main co-ordination center of the human nervous system, composed of a cerebrum, cerebellum, and medulla
breed: to produce and nourish offspring; a race or variety related by descent
brine (brīn): a strong salt solution
bronchi (brŏng′kī, plural of **bronchus**): the subdivisions of the trachea, or windpipe
butadiene (bū′tȧ dī′ēn): a substance produced when petroleum is purified, used in making synthetic rubber
bŭtyl (bū′tĭl) **rubber:** a synthetic rubber valuable for its air-sealing qualities

cadmium (kăd′mĭ ŭm): a white, ductile, metallic element that is used to control the flow of neutrons in an atomic pile
calm: no wind blowing or a wind of one mile per hour or less, smoke rises vertically
calorie (kăl′ô rĭ): the amount of heat required to raise the temperature of one gram of water one degree centigrade (a large calorie is 1,000 small calories)
calorimeter (kăl′ô rĭm′ê tẽr): an apparatus for measuring quantities of heat in foods or other substances
cancer: an abnormal harmful growth of cells
candle power: the unit of measurement for light, based on the light given out by a standard candle
capillaries (kăp′ĭ lĕr′ĭz): the smallest blood vessels in the body
carbohydrate (kär′bô hī′drāt): any of a group of compounds including the sugars, starches, and celluloses
carbon dioxide: CO_2; a heavy colorless gas breathed out by animals and absorbed by plants
carnivores (kär′nĭ vōrz): flesh-eating animals
carrier wave: an oscillating radio wave that carries a broadcast from the transmitting antenna to an aerial of a radio receiver
cartilage (kär′tĭ lĭj): an elastic, yet hard, tissue composing most of the skeleton of the embryos and of the very young of all vertebrates; found in the ear, nose, and breastbone of adults
casein (kā′sê ĭn): a protein found in milk
cast iron: iron that is fusible and brittle
cathode-ray (kăth′ōd) **tube:** a type of vacuum tube in which a stream of electrons is directed by an electric or magnetic field; for example, the iconoscope tube and kinescope tube used in television
Caucasoid (kô′kȧ soid): one of the three races of man
C.C.C.: Civilian Conservation Corps, which planted billions of trees during the 1930's as a part of the government's forest conservation program
cell: the unit of structure and function of an organism
cell membrane: the thin outer layer of cytoplasm acting as a cell boundary; it governs diffusion of molecules
cellophane (sĕl′ô fān): a plastic made from wood or cotton
celluloid (sĕl′ū loid): a substance composed of pyroxylin and camphor
cement: a mixture of clay and limestone used in making concrete for building
centigrade (sĕn′tĭ grād) **thermometer:** a thermometer that has one hundred degrees or divisions between the freezing and boiling points of water; 0° C. is the freezing point and 100° C. is the boiling point
central heating: a method of heating an entire building from one central furnace usually located in the basement
cerebellum (sĕr′ê bĕl′ŭm): a portion of the brain controlling balance and muscular co-ordination
cerebrum (sĕr′ê brŭm): a portion of the brain of vertebrates concerned with thought and judgment
chemical energy: energy produced by a chemical change in a substance
chlorine (klō′rēn): a poisonous, greenish-yellow, gaseous element
chlorophyll (klō′rô fĭl): a substance which enables green plants to make glucose (grape sugar)
chloroplast (klō′rô plăst): small green bodies, located in the cytoplasm of a plant cell, which contain chlorophyll
chromium (krō′mĭ ŭm): a grayish-white metallic element used in making alloys and in plating metals
chromosome (krō′mô sōm): one of the small bodies found in the nucleus; it contains the genes which transmit hereditary traits
circuit, electric: the path of an electric current from and back to the generating source
circuit, radio: the path through which the electrons flow in a radio receiver
classification: a systematic arrangement of plants and animals based on inherited characteristics
clay: finely ground quartz, feldspar, and mica; a result of erosion of rocks
cloud: a sky formation of tiny droplets of water
cloud chamber: an instrument used to trace the paths of atomic particles
clutch: a device that engages or disengages the transmission from the engine of an automobile
coccus (kŏk′ŭs): a spherical bacterium
cochlea (kŏk′lê ȧ): a coil-like structure in the inner ear by which sounds of different frequencies are distinguished
cocoon (kŏ ko͞on′): the silky envelope in which the larvae of certain insects pass the pupa stage
cold-blooded animal: an animal whose body temperature varies with changes in the outer temperature

cold front: the boundary along which a mass of cooler air is moving in and under a mass of warmer air

combustibility (kŏm bŭs′tĭ bĭl′ĭ tĭ): having the properties necessary for kindling

comet: a kind of heavenly body which develops a long, cloudy train or tail as it approaches the sun

compass (kŭm′pȧs): a freely turning magnet and a dial marked off in degrees with reference to the magnetic poles of the earth; used in navigation to keep a course

competitors (kŏm pĕt′ĭ tẽrz): organisms which rival each other for food, room, light, moisture, or a mate

compound: a substance composed of or formed by two or more elements chemically united

compression stroke: the stroke on which the piston of an engine moves toward the end of the cylinder, compressing the explosive mixture in the cylinder before it is ignited

compressor: a device for compressing a large amount of gas in a small space, such as the air compressor at a filling station

concave (kŏn′kāv) **lens:** a lens which makes light rays spread apart

concrete: a mixture of sand or gravel with cement and water which becomes hard as rock

condensation: the process of reducing a gas or a vapor to a liquid or a solid

conditioned act: an acquired automatic response to a stimulus

constellation: any one of the 88 groups of stars and the area of the sky in its vicinity to which a definite name has been given, for example, Ursa Major, the Great Bear

contact poison: a chemical which kills insects as it comes in contact with their bodies; used especially to kill insects with sucking mouth parts

contour (kŏn′to͝or) **plowing:** plowing which follows the shape or outlines of hilly land

convection (kŏn vĕk′shŭn) **current:** the movement of warm air upward as cooler air moves in to replace it

convex (kŏn′vĕks) **lens:** a lens which makes light rays come together at a point called the focus

co-operative observer: a person who serves as an observer for the U.S. Weather Bureau without pay

cornea (kôr′nē ȧ): the transparent tissue in front of the iris and pupil of the eye

corona (kō rō′nȧ): a bright white light which surrounds the moon and sun for a few seconds when the sun is totally eclipsed by the moon

cracking: a process by which the higher boiling oils of petroleum are separated from other parts; used in making gasoline

Cro-Magnon (krō′mȧ′nyôɴ′) **man:** a type of man living in middle Europe about 50,000 years or so ago

crop rotation: a farming method in which different plants are grown in the same soil in succeeding years; for example, during a three-year period corn, oats, and clover are rotated on the same field

cross-pollination: the carrying of pollen from one flower to the stigma of another, as by insects, wind, or birds

curium (kū′rĭ ŭm): one of the four new elements made by man

current, electric: the flow of electricity through a conductor, measured in terms of amperes

cutting: any cut portion (leaf, stem, or root) of a plant used for asexual reproduction

cyclone (sī′klōn): winds blowing counterclockwise about a nearly circular region of low air pressure in the Northern Hemisphere over an area covering thousands of square miles

cyclotron (sī′klō trŏn): an instrument used to study the properties of atoms by means of speeding atomic particles

cylinder (sĭl′ĭn dẽr): the hollow chamber in an engine in which the piston moves

cytoplasm (sī′tō plăz′m): the more fluid portion of the protoplasm in a cell, as distinct from the nucleus

day: on the earth, a period of 24 hours during which the earth makes one complete rotation on its axis

dead air space: a volume of air which is confined and therefore cannot circulate or transmit heat by convection

deficiency disease: a disease caused by a lack of vitamins or minerals or other essential nutrient substances

degenerative (dē jĕn′ẽr ā′tĭv) **diseases:** diseases usually associated with old age, such as arthritis, high blood pressure

delta: a deposit of soil at the mouth of a river

deoxygenated (dē ŏk′sĭ jĕn āt′ĕd) **blood:** blood, returning from body cells, deficient in oxygen

development: the growth of a plant or an animal

diaphragm (dī′ȧ frăm): a sheet of muscle which separates the chest cavity from the abdomen and by its contraction helps cause inhalation

Diesel (dē′zĕl) **engine:** a modified form of the gasoline engine using heavy oil instead of gasoline as a fuel

differential (dĭf′ẽr ĕn′shăl) **gears:** an arrangement of gears in the rear axle of an automobile that allows one of the wheels to go faster than the other, as in going around curves

diffusion (dĭ fū′zhŭn): the process whereby the particles of substances tend to intermingle, as when two gases or solutions are brought into contact

digestion: the act or process of changing complex molecules of food to simpler molecules by means of enzymes

dinosaur (dī′nō sôr): any of a group of extinct reptiles which lived in prehistoric times

direct current: a movement or flow of electricity that does not alternate

distillation (dĭs'tĭ lā'shŭn): the process of heating a substance until it turns into a gas and of condensing this gas by cooling

doldrums (dŏl'drŭmz): a belt of calms in the vicinity of the equator

dominant trait: an inherited characteristic which always appears when genes for it are present in the individual, for example, tallness in the pea plant, dark hair in man

dormant (dôr'mănt): inactive, or not growing; said especially of buds and seeds during winter

drag: the force exerted to reduce the forward motion of the plane

dry cell: a voltaic cell such as that used in a flashlight battery; it makes use of a carbon rod, manganese dioxide, ammonium chloride, and zinc to produce an electric current

dynamo (dī'nȧ mō): a device used to produce electricity by use of mechanical energy

eardrum: a membranous sheet in the ear which vibrates as sound waves strike it

earthquake: a vibration of the earth's crust caused by the movement of rocks along a fault or by the eruption of a volcano

echo (ĕk'ō): a sound reflected from a wall or cliff so that it may be heard again at the source of the sound after a brief interval

eclipse (ė klĭps'), **lunar:** the passing of the moon into the shadow cast by the earth

eclipse, solar: the passing of the earth into the shadow cast by the moon

ecologist (ė kŏl'ȯ jĭst): a scientist who studies how plants and animals live together in their environment

egg: a female sex cell which may be fertilized by a sperm

electric conductor: any material used to conduct electricity, such as copper

electricity: an accumulated charge or flow of electrons from one place to another

electric meter: a device which measures electric energy or the power generated by it; for example, the electric meter which registers in kilowatt hours the amount of electricity used by a consumer

electric motor: a device that transforms electric energy into mechanical work; it consists of a powerful field magnet between the poles of which an armature (consisting of thousands of coils of wire carrying an electric current) is caused to rotate by attraction and repulsion of unlike and like magnetic poles

electromagnet (ė lĕk'trȯ măg'nĕt): a core of soft iron surrounded by a coil of wire through which an electric current passes, thus magnetizing the core

electron (ė lĕk'trŏn): a tiny particle of matter found in a ray thrown off from exploding atoms of radium; a negative particle revolving about the nucleus of an atom

element: a substance that cannot be divided into units different from itself by ordinary means; for example, oxygen, iron

Elodea (ė lō'dė ȧ): a common water plant, often used in fish tanks

embryo (ĕm'brĭ ō): an organism in the early stage of development

energy: the capacity to do work; that is, to move objects

entomologist (ĕn'tȯ mŏl'ȯ jĭst): a scientist who studies insects

environment (ĕn vī'rŭn mĕnt): the surrounding conditions in which organisms live

enzyme (ĕn'zīm): a substance (for example, pepsin) which breaks down nutrients into simple substances

equinox (ē'kwĭ nŏks): a moment occurring twice each year on or about March 21 and September 23 when the sun appears to cross the celestial equator

erosion (ė rō'zhŭn): the act of wearing away, as land by the action of wind or water

Eustachian (ū stā'kĭ ăn) **tube:** an air tube leading from the back of the mouth to the cavity of the middle ear

evaporation (ė văp'ȯ rā'shŭn): the process of changing a liquid into a gas

excretion (ĕks krē'shŭn): the process of removing wastes, as by kidneys and skin

exfoliation (ĕks fō'lĭ ā'shŭn): the flaking off of surface layers, as in rocks

exhaust stroke: the stroke on which the piston of an engine forces gases from burned fuel out of the cylinder

Fahrenheit (făr'ĕn hīt) **thermometer:** a thermometer graduated so that the freezing point of water is at 32° above zero, the boiling point at 212° above zero

fat: stored tissue deposited in special cells, called fat cells; a nutrient found in foods, used by the body as a source of energy

fault: a dislocation in the earth caused by the slipping of rock masses along a crack

fertilization (fûr'tĭ lĭ zā'shŭn): the union of a male sex cell (or sperm) with a female sex cell (or egg)

fertilizer (fûr'tĭ līz'ẽr): material added to soil to restore its minerals and organic matter

film slide: a lantern slide consisting of a piece of film bearing images mounted for projection (usually in a holder 2″ × 2″)

film strip: a length of film bearing a series of images which are projected on a screen one at a time

filtration (fĭl trā'shŭn) **bed:** layers of sand and gravel which catch soil and other particles as water passes through

first-class lever: a lever in which the fulcrum is between the force and the resistance

fish: a gill-breathing, water-living vertebrate covered with a scaly skin

flower: an organ of a plant used in sexual reproduction

fly wheel: a heavy wheel that rotates steadily and thus regulates the speeds of machinery to which it is attached

focus (fō'kŭs): the point at which light rays are brought together (or seem to be brought together) by a lens or mirror

fog: a cloud of condensed water vapor formed on or near the ground

food: any substance used by plants or animals for growth, energy, and repair of body tissues or other essential life processes

foot-candle: the amount of illumination received by a surface at a distance of one foot from a standard one candle power source of light

fossils (fŏs'ĭlz): remains or imprints of ancient life, usually found in rock

frequency: the number of waves per second; for example, sound waves, radio waves, light waves

friction: the resistance of two surfaces sliding over one another

front: the boundary region where one mass of air meets another mass of air of a different type

fruit: the ripened ovary of a seed plant and its contents (seeds)

fulcrum (fŭl'krŭm): the point of rest upon which a lever turns in moving an object

fungus (fŭng'gŭs): a plant of simple structure which lacks chlorophyll and therefore cannot carry on photosynthesis; for example, bread mold

fuse: a device to break an electric circuit that is overloaded

fuselage (fū'zĕ lĭj): the body of an airplane which holds the engine, passengers, cargo, etc., and to which are attached the wings and the tail

galaxy (găl'ăk sĭ): a star system or cluster of stars; for example, the Milky Way

gale: a wind with a speed of 39–54 miles per hour

galena (gȧ lē'nȧ): native lead sulphide; the chief ore of lead, which often contains enough silver to rank as silver ore

galvanization (găl'vȧ nĭ zā'shŭn): a process whereby a coating of zinc is given to iron to protect its surface

gas: an airlike substance having no independent shape or volume, but able to expand indefinitely

gasoline engine: an internal-combustion engine which uses the heat energy of gasoline for its operation

gastric (găs'trĭk) **juice:** a digestive juice secreted by the stomach, containing the enzyme pepsin

G.C.A.: Ground Control of Approach; consists of tracking a plane, reporting its position to the pilot, and "talking him down" by radio

gene (jēn): one of the particles in a chromosome which transmit hereditary traits

geologist (jē ŏl'ō jĭst): one who studies the history, composition, and structure of the earth and its rocks

geriatrics (jĕr'ĭ ăt'rĭks): a new field of medicine which specializes in the health problems of old age

glacier (glā'shēr): a body of ice which is formed in a region of perpetual snow and moves slowly down a mountain slope or valley

gland: a secreting organ of the body, such as the glands which secrete saliva

glucose (glōō'kōs): a simple sugar which is soluble and does not require digestion

glycogen (glī'kō jĕn): a type of animal starch stored in the liver and in the muscles

grafting: joining the cut branch of one plant to that of a rooted plant which supplies water and minerals

gramicidin (grăm'ĭ sī'dĭn): a germ killer produced by soil bacteria

granite (grăn'ĭt): a very hard crystalline, granular rock consisting mainly of quartz, feldspar, and hornblende

gravity (grăv'ĭ tĭ): the force that holds everything to the earth

Greenwich (grĭn'ĭj): a city in England now part of London; the meridian of longitude passing through Greenwich is regarded as one boundary (0°) between east and west longitude

grid: the portion of a radio tube which controls the flow of electrons from filament to plate

gristle (grĭs''l): fairly hard cartilage

guard cells: two sausage-shaped cells surrounding an opening or stomate in a leaf; they usually cause the stomate to open and close

gusher: an extremely large flow of petroleum from an oil well

habit: a learned, automatic act

hail: a form of precipitation, consisting of small balls or lumps of ice, which usually falls during a thunderstorm (never when the surface temperature is below freezing)

hard water: water containing a large quantity of dissolved mineral salts

heart: a hollow muscular organ whose beat keeps up the circulation of the blood

helicopter (hĕl'ĭ kŏp'tēr): an airplane that is supported by the reaction of a stream of air driven downward by propellers revolving on a vertical axis

helium (hē'lĭ ŭm): a rare gaseous element in the sun's atmosphere; also found on earth

hematite (hĕm'ȧ tīt): an important ore of iron

hemoglobin (hē'mō glō'bĭn): the iron-containing red substance found in the red blood cells (carries oxygen)

herbivores (hûr'bĭ vōrz): plant-eating animals

heredity (hē rĕd'ĭ tĭ): the transmission of characteristics through the parents to offspring

herpetologist (hûr'pē tŏl'ō jĭst): a specialist in the study of reptiles

hibernation (hī′bẽr nā′shŭn): the act of sleeping throughout some or all of the winter season

high-frequency waves: waves occurring so rapidly that each is completed during a tiny fraction of a second

hormones (hôr′mōnz): substances which are secreted into the blood and which help regulate growth, weight, behavior, and other life processes

horse latitudes: two regions of light variable winds ranging from calms to gales which move northward and southward with the sun in the vicinity of 35° north and 35° south latitude

horsepower: a unit for measuring rate of work, equal to 550 foot-pounds per second

hour: a period of time during which the earth completes $\frac{1}{24}$ of a rotation on its axis and during which the sun appears to have traveled toward the west a distance of 15° longitude

humidifier (hū mĭd′ĭ fī′ẽr): a device used to add moisture to indoor air

humidity: refers to the amount of water vapor in the air

humus (hū′mŭs): a brown or black material in soil formed by partial decomposition of dead plants and animals or parts of them (leaves, etc.)

hurricane (hûr′ĭ kān): a wind in excess of 75 miles per hour, usually originating as a tropical cyclone

hydrophobia (hī′drō fō′bĭ ȧ): a disease caused by a virus infection which is transmitted through the saliva of an animal; also called rabies

hydrosphere (hī′drō sfēr): the waters covering the surface of the earth

hypothesis (hī pŏth′ē sĭs): an idea or tentative statement not yet proved and depending on further facts for its proof

iconoscope (ī kŏn′ō skōp): a cathode-ray tube used in a television camera to change images into electric impulses which can be transmitted

igneous (ĭg′nē ŭs) **rock:** fused rock resulting from the action of intense heat

impulse: that which travels along nerve cells or fibers

inbreeding: the mating of closely related organisms, such as self-fertilized plants

inclined plane: a sloping plane that makes an angle with a horizontal surface

Industrial Revolution: the revolution in industry with accompanying social changes brought about by invention of new machinery powered by the steam engine

inertia (ĭn ûr′shȧ): the property of a body to remain at rest or in uniform motion in the same straight line unless acted upon by some external force

inheritance (ĭn hĕr′ĭ tăns): the passing on from parent to offspring of genes which influence the development of traits in a plant or an animal

inoculation (ĭn ŏk′ū lā′shŭn): injection of a vaccine or an antitoxin to produce immunity

instinct (ĭn′stĭngkt): an inherited form of behavior; a series of reflexes

insulation: any material which is used to reduce the transfer of heat or to shield a conductor of electricity

insulin (ĭn′sū lĭn): a secretion from the pancreas which is used in the control of diabetes

intake stroke: the stroke on which the piston of a gasoline engine draws a mixture of fuel and air into the cylinder

internal-combustion engine: an engine in which the source of power is the explosion of a mixture of gasoline and air, or a mixture of oil and air, inside the cylinder

international date line: a map boundary (drawn to avoid all land areas) between west and east longitude which lies on or near the 180th meridian

interplanetary (ĭn′tẽr plăn′ē tĕr′ĭ) **space:** the space between or in the region of the planets

intestine (ĭn tĕs′tĭn): a section of the digestive system in which digestion and absorption of substances takes place

invertebrate (ĭn vûr′tē brāt): an animal having no backbone

ionosphere (ī ŏn′ō sfēr): the highest region of the atmosphere which is beginning to be explored by means of high-altitude rockets

iris (ī′rĭs): the doughnut-shaped muscular screen of the eye, usually colored, which surrounds the pupil

irrigation (ĭr′ĭ gā′shŭn): supplying land with water by means of canals and ditches

isobar (ī′sō bär): a line on a weather map connecting observatories reporting the same barometric pressure

isotherm (ī′sō thûrm): a line on a weather map connecting observatories reporting the same temperature; usually only the 0° F. and 32° F. isotherms are shown

Java man: an ancient type of primitive man; fossil fragments have been found

jet engine: an engine with one or more combustion chambers and one or more exhaust nozzles for discharging a continuous flow of exhaust force

Jupiter (jōō′pĭ tẽr): the largest planet and the brightest except Venus; its orbit is between Mars and Saturn; it has 12 moons

kidney (kĭd′nĭ): one of the two organs which excrete liquid wastes

kilowatt (kĭl′ō wŏt′) **hour:** a unit of energy equivalent to that expended in one hour by one thousand watts of electric power

kindling temperature: the temperature at which a fuel begins to burn in air

kinescope (kĭn′ē skōp): the cathode-ray tube used in a television receiver to reproduce the image

kinetic (kĭ nĕt′ĭk) **energy:** energy of motion, as in a moving automobile

Kingston valves: valves in a submarine that when opened allow water to rush into the ballast tanks

kudzu (ko͝od′zo͞o) **vine:** a vine that spreads rapidly and is used to hold the soil in which it is planted

lacteal (lăk′tē ăl): a vessel which is found in each villus and absorbs digested fat from the small intestine

land breeze: a breeze blowing from the land toward a large body of water

lanital (lăn′ĭ tăl): a fiber made from casein in skimmed milk

lantern slide: an image or picture on a piece of glass or plastic material so mounted between pieces of glass that the shadow cast by the image may be projected by a stereopticon

larva (lär′vȧ): the young of some animals, especially insects; for example, the grub of a beetle or the caterpillar of a moth

latex (lā′tĕks): a milky fluid found in certain plant cells; for example, milkweeds and the bark of rubber trees

lava (lä′vȧ): fluid rock that issues from a volcano

Law of Gravitation: a law stating that every object in the universe attracts every other object

layering: a method of vegetative propagation in which a stem is turned back into the soil and grows new roots, stems, and leaves

leguminous (lē gū′mĭ nŭs) **plant:** a member of the pea family; for example, peas, beans, clover, alfalfa

lemming (lĕm′ĭng): a small arctic rodent with short tail, furry feet, and small ears

lens: a piece of transparent material such as glass which is used to bend rays of light

lever: a bar used to move some object with use of a fulcrum

life activities: all the functions carried on by plants and animals to maintain growth, reproduction, and survival

lift: air pressure under the wing of a plane

lightning: an electric discharge between two clouds, between a cloud and the earth, or between two parts of the same cloud

lightning rod: a large metal conductor used to carry electrostatic charges safely to the ground and thus prevent damage to property by lightning

light-year: the distance which light, traveling at 186,000 miles per second, travels in a year

limestone: a rock consisting chiefly of calcium carbonate

lines of force: lines in a field of force of any magnet that show the amount and direction of the field

liquid: any substance that flows more or less freely, like water

lithosphere (lĭth′ō sfēr): the rock crust of the earth

loam (lōm): ordinary garden soil, a loose soil composed mainly of clay and sand and a small amount of humus

longitude (lŏn′jĭ tūd): distance on the earth's surface measured in degrees east or west of the meridian of Greenwich

lucite (lū′sīt): a sparkling, transparent plastic

luminous (lū′mĭ nŭs): giving out light rays

lunar (lū′nẽr) **month:** a period of complete revolution of the moon around the earth accomplished in 29 days, 12 hours, 44 minutes, and 27 seconds

lungs: two organs, composed mainly of thin-walled air pockets through which oxygen, carbon dioxide, and water vapor diffuse

lymph (lĭmf): a colorless fluid bathing all cells and closely resembling blood plasma

machine: any device which transmits force and motion to do work

maggot (măg′ŭt): the soft-bodied grublike larva of a fly

magnesium (măg nē′shĭ ŭm): a silvery-white metallic element, ductile and light

magnetic field: the area in the vicinity of a magnet or an electric current in which magnetic lines of force can be noted

mammal (măm′ăl): one of the class of vertebrates that suckle their young

mammary (măm′ȧ rĭ) **glands:** organs that secrete milk, characteristic of all mammals

mammoth (măm′ŭth): a large, extinct species of animal similar to the elephant

manganese (măng′gȧ nēs): a hard, brittle metal, grayish-white tinged with red; it rusts like iron but is not magnetic

Manhattan District Project: a name given to the project in which scientists worked on splitting the atom

Mars (märz): one of the planets of the solar system notable for its red light; its orbit is between earth and Jupiter; this planet has two moons

matter: any substance that occupies space

mauve (mōv): a delicate purple coal-tar dye first made by William Perkin

medulla (mē dŭl′ȧ): a portion of the brain connecting with the spinal cord

membrane (mĕm′brān): a thin, soft sheet of animal or plant tissue; also the outer edge of the cytoplasm of every living cell

Mercury (mûr′kū rĭ): the planet of the solar system nearest to the sun; this planet has no moon; also, a liquid metallic element known as "quicksilver"

metallurgy (mĕt′′l ûr′jĭ): the science of preparing metals for use from their ores

metamorphic (mĕt′ȧ môr′fĭk) **rock:** rock in a compact condition changed from its original form by pressure, heat, and water

meteor (mē′tē ẽr): a heavenly body which glows

for a moment as it passes through the atmosphere, a "shooting star"

meteorite (mē'tē ẽr īt): a meteor that has struck the earth's surface

meteoroid (mē'tē ẽr oid'): a small dark object passing through space but not yet within the earth's atmosphere

meteorologist (mē'tē ẽr ŏl'ō jĭst): an expert in studying the atmosphere and its variations of weather

methane (mĕth'ān): a gas, odorless and inflammable, often encountered in coal mines

mica (mī'kȧ): a mixture of silicate minerals that may easily be separated into very thin transparent sheets

microbe (mī'krōb): a microscopic organism

microscope (mī'krō skōp): an instrument consisting of a lens or a combination of lenses for making enlarged images of very small objects

microwaves: ultra-high-frequency radio waves such as are used in radar for scanning a certain section of the sky, sea, or land

migration (mī grā'shŭn): a movement of organism from one area to another, usually a mass movement

mildew (mĭl'dū): any whitish or spotted discoloration caused by parasitic fungi on plants; also a type of fungus

Milky Way: the luminous belt of starlight seen at night, stretching across the heavens; the galaxy of stars of which our sun is a member

millibar (mĭl'ĭ bär): a unit of pressure equal to one one-thousandth of a bar; 1,013 millibars is standard atmospheric pressure at sea level

mineral: any chemical element or compound occurring free or in rocks

Mindanao (mĭn'dȧ nä'ō) **Deep:** the greatest ocean depth recorded, near the Philippines, 35,400 feet (also called the Emden Deep)

mixture: two or more substances mixed together in no definite proportions and not chemically united; air is a mixture, pure water is a compound

mold: a fungus; for example, bread mold; fungi have no chlorophyll

molecular (mō lĕk'ū lẽr) **vibration:** a state of motion of molecules

molecule (mŏl'ē kūl): the smallest part of any substance that has the properties of that substance

Mongoloid (mŏng'gŏl oid): one of the three races of man

monsoon (mŏn sōōn'): a seasonal wind blowing from a large land area to the ocean in winter and oppositely in the summer (most pronounced in India)

moon: the satellite of the earth revolving about it from west to east

Morse code: a system of dot and dash signals used in communication and named for its inventor

mortar: a building material made of lime, cement, or plaster, with sand and water

mosaic (mō zā'ĭk): the screen in the iconoscope containing numerous photoelectric cells

Mount Palomar (păl'ō mär): a mountain in California on which is located the Hale telescope, the world's largest reflecting telescope with the famous 200-inch mirror

mucous (mū'kŭs) **membrane:** a tissue of flat cells lining the cheek, gullet, stomach, and intestines

mucus (mū'kŭs): a sticky substance produced by the mucous membranes

mutant (mū'tănt): an animal or a plant which differs from the parents in having one or more new traits which can be inherited

nationality: refers to the country in which a person was born or the group of customs he follows

Neanderthal (nā än'dẽr täl') **man:** a species of man living in Europe prior to Cro-Magnon man

Negroid (nē'groid): one of the three races of man

neon (nē'ŏn): an inert gaseous element occurring in the air

neoprene (nē'ō prēn): an artificial rubber that can stand high degrees of heat

Neptune (nĕp'tūn): a planet of the solar system between Uranus and Pluto; discovered in 1846, this planet has two moons

neptunium (nĕp tū'nĭ ŭm): one of the four new man-made elements

nerve cell: an animal cell which is sensitive to a stimulus and carries an impulse

nerve pathway: a series of nerve cells through which an impulse travels

neutron (nū'trŏn): a neutral particle in the nucleus of the atom

niacin (nī'ȧ sĭn): a vitamin which prevents pellagra

nitrogen (nī'trō jĕn): an inactive gaseous element making up about 80 per cent of the air

nitrogenous (nī trŏj'ē nŭs): of or pertaining to nitrogen

nodules (nŏd'ūlz): swellings on the root of a plant, generally referring to the nodules on the roots of leguminous plants like peas and clover

nucleus (nū'klē ŭs): a rounded or oval mass of protoplasm, present in most plant or animal cells, containing chromosomes; also the central part of an atom

nutrient (nū'trĭ ĕnt): one of six types of substances used in nourishing, repairing body tissue, and promoting growth

nymph (nĭmf): an immature stage of certain insects resembling the adult, like the grasshopper

nylon (nī'lŏn): a man-made chemical product which may be formed into fibers having extreme toughness, elasticity, and strength

orbit (ôr'bĭt): the course described by a heavenly body in its path around another body

ore: a mineral from which one or more metals can be extracted

organ: any group of tissues performing a special function in a plant or an animal; for example, stomach, eye, hand, leaf, root

oscillator (ŏs′ĭ lā′tẽr): anything that vibrates rapidly, particularly a radio transmitter which sends out radio waves

ovary (ō′vȧ rĭ): an egg-producing organ in a female plant or animal

oxidation (ŏk′sĭ dā′shŭn): the slow burning of food which takes place in cells; the release of energy, as in the burning of a candle

oxygen: a gaseous element making up about 20 per cent of air

oxygenated (ŏk′sĭ jĕn āt′ed) **blood:** blood rich in oxygen

pancreatic (păng′krē ăt′ĭk) **juice:** a secretion of the pancreas containing three powerful enzymes which digest starch, protein, and fats

parallel connection: an arrangement of an electric system in which all positive poles are joined to one conductor, all negative poles to another conductor, each connection between the two being parallel to the other

partial eclipse: the incomplete hiding or darkening of one heavenly body by another

pellagra (pĕ lā′grȧ): a deficiency disease caused by a lack of a vitamin called niacin

penicillin (pĕn′ĭ sĭl′ĭn): a chemical secreted by Penicillium, a mold; discovered by Sir Alexander Fleming; it prevents the growth of certain bacteria

Penicillium (pĕn′ĭ sĭl′ĭ ŭm): a green or blue mold; secretes penicillin

penumbra (pē nŭm′brȧ): the lighter portion of a shadow

periscope (pĕr′ĭ skōp): a device using a tube in which mirrors at opposite ends are placed at an angle of 45° so that they will reflect rays of light from an object to the eyes of a hidden observer

persistence of vision: the ability of the retina to retain an image at least $\frac{1}{16}$ of a second

phases: changing views of the moon or the planets Mercury and Venus as seen by an observer on the earth

photoelectric (fō′tō ē lĕk′trĭk) **cell:** a cell or vacuum tube used to produce an electric current varying in accordance with a varying source of light, as in the sound-producing part of a motion picture projector

photosynthesis (fō′tō sĭn′thē sĭs): the process by which a plant containing chlorophyll makes sugar in the presence of light from water and carbon dioxide

pistil: the female reproductive organ of a flower containing an ovary with its ovules

piston: a sliding piece of metal, usually a short cylinder, that moves back and forth inside a larger cylinder

piston ring: a steel ring that seals the space between the piston and the cylinder walls of an engine

pitch: a certain number of vibrations per second (all instruments vibrating 435 times per second produce the sound or pitch of the note A)

pitchblende (pĭch′blĕnd′): a dark earthy ore of uranium

plasma (plăz′mȧ): the liquid portion of the blood, largely water and containing minerals and other soluble foods, in which the white and red corpuscles are carried

plastic: a substance capable of being molded or modeled, such as bakelite

Pluto (ploo′tō): the most distant and most recently discovered (1930) planet of the solar system

plutonium (ploo tō′nĭ ŭm): a man-made element produced from uranium in an atomic pile

polarized (pō′lẽr īzd) **light:** light that has different characteristics in one direction than it has in another

pollination (pŏl′ĭ nā′shŭn): the transfer of pollen from the anther to the stigma of the same or a different flower

power stroke: the stroke on which the piston is forced away from the head of the cylinder by the explosion of a mixture of gasoline and air, or of oil and air

precipitation (prē sĭp′ĭ tā′shŭn): a term covering all forms of water falling from the sky; hail, snow, rain, and sleet

prehistoric (prē′hĭs tŏr′ĭk): a period in the earth's time before recorded history

properties of matter: characteristics, both physical and chemical, that define matter by telling how it looks and what it does

protein: a nutrient in food containing nitrogen; necessary for growth of protoplasm

proton (prō′tŏn): an atomic particle having a single positive charge and a weight of one; in the hydrogen atom the proton is the nucleus; in other atoms the nucleus consists of protons and other particles

protoplasm (prō′tō plăz′m): the semisolid, jellylike material of all living cells; including the nucleus, cytoplasm, and membrane of cells

protozoa (prō′tō zō′ȧ): single-celled animals, such as paramecium or amoeba, which are usually found in pond water (a few cause diseases like malaria)

psychrometer (sī krŏm′ē tẽr): an instrument used to determine the percentage of relative humidity

ptomaines (tō′mānz): poisonous substances formed by the action of certain bacteria

pulley: a wheel with a grooved rim used with a rope or chain to change the direction of a pulling force

pupa (pū′pȧ): the inactive stage in the development of an insect passing through egg, larva, pupa, and then adult stages

pus: a milky fluid, composed of living and dead bacteria and white corpuscles and cells

quarantine (kwŏr′ăn tēn): isolation of any organism which carries a contagious disease

quinine (kwī′nīn): a drug used in preventing and treating malaria

race: a large group of people having in common certain traits which are inherited

radar (rā′där): the abbreviation for Radio Detection and Ranging, the device which is used for detection of objects by radio

radiant energy: the energy associated with waves or rays traveling through space

radiation: the process by which energy is transferred in the form of electromagnetic waves; also, radiant energy

radiator (rā′dĭ ā′tẽr): a metal pipe of large surface area used for the heating of indoor air or for the removal of heat from an engine or refrigerator

radioactivity (rā′dĭ ō ăk tĭv′ĭ tĭ): the property possessed by certain elements of naturally emitting radiant energy through atomic disintegration; also characteristic of substances made radioactive in the atomic pile

radiosonde (rā′dĭ ō sŏnd′): a radio transmitter attached to a balloon and sent aloft by observers seeking information regarding weather conditions in the upper atmosphere

radium (rā′dĭ ŭm): an intensely radioactive metallic element found in minute quantities in pitchblende

rain gage: a device used for measuring and sometimes recording the amount of rainfall

receiver, radio: an apparatus (like your radio) which receives signals sent out by a transmitter and demodulates (changes) these signals so that they may be heard as speech, music, or code signals

recessive trait: an inherited characteristic which will not develop in a plant or an animal if the plant or animal contains any genes for the opposite dominant trait

red blood cell: a blood cell containing hemoglobin which carries oxygen through the body

reflex: an inborn automatic act (conditioned reflexes are acquired)

refrigerant (rē frĭj′ẽr ănt): a liquid which evaporates easily and therefore is useful in the cooling coils of a refrigerator

relay: an electric device used to open or close circuits under remote control

remote control: a method by which a person may control the operation of a device without personal contact with it

reptile (rĕp′tĭl): an air-breathing vertebrate having a scaly skin, and usually laying eggs; for example, turtle, snake, lizard

response: the reaction of a plant or an animal to some stimulus

retina (rĕt′ĭ nȧ): the inner lining of the eye, containing light-sensitive nerve cells called rods and cones

revolution: a single cycle of a heavenly body about another heavenly body; for example, the earth's yearly revolution about the sun

rickets: a deficiency disease caused by a lack of vitamin D, characterized by soft bones and teeth since calcium is not properly used

rocket: a device consisting of a combustion chamber and an exhaust nozzle supplied with fuel and the oxygen necessary for combustion

root hair: a root cell from which a hairlike extension grows out; it increases absorption of water and minerals

rotation: the motion of any object about a central axis

rudder: a flat piece of fabric-covered wood, or a piece of metal, hinged to the vertical fin of an airplane to control its direction to the right or left; also a device for steering a boat

rust: a parasitic fungus, related to the smuts

safety valve: a valve on a steam boiler that allows steam to escape when a certain pressure is reached to prevent an explosion

sanctuary (săngk′tū̍ ẽr′ĭ): a haven for wild animals where hunting is prohibited or regulated

sandstone: a sedimentary rock consisting of sand, usually with silica as a binder

saturated (săt′ū̍ rāt′ĕd) **solution:** a solution containing all the dissolved material it can hold under existing conditions

Saturn (săt′ẽrn): the second largest planet of the solar system and the sixth in distance from the sun; through a telescope it may be recognized by the three rings of moonlets that surround it

screw: a simple machine consisting of a continuous rib, or thread, winding spirally around a central rod

scurvy (skûr′vĭ): a deficiency disease due to a lack of vitamin C; bleeding under the skin is a characteristic of this disease

sea breeze: a breeze blowing from a large body of water toward the land

season: a period of the year marked by certain characteristic conditions of the weather, plant growth, etc.

second-class lever: a lever in which the resistance is between the fulcrum and the force

sedimentary (sĕd′ĭ mĕn′tȧ rĭ) **rock:** formed from deposits of sediment and hardened into masses, as limestone or sandstone

seed: the fully developed ovule of a plant containing stored food together with the embryo plant

seismograph (sīz′mō grăf): an extremely sensitive instrument used to record vibrations of the earth's crust and to detect the location of earthquakes

selection: choosing the most desirable plants or animals to become the parents of the next generation

series connection: a connection joining parts of an electric circuit (+ to −) to form a single path for the current

sexual reproduction: production of a new organism from the union of two cells, male and female (sperm and egg)

shale (shāl): a rock formed from compressed silt or mud, which splits easily into layers

silicone (sĭl'ĭ kōn) **rubber:** a soft, rubberlike material made from silica that retains its rubberlike qualities at extreme ranges of temperature

slag (slăg): the waste left after the separation of metals from their ores

slate: a dense, fine-grained rock that splits into thin layers

slide valve: that part of the steam engine whose action controls the timing of the entrance of steam into the cylinder of the engine and its exhaust

smog: a mixture of smoke and fog

smut: a parasitic fungus, related to the rusts

soft water: water that is relatively free from mineral salts

solid: a rigid, compact body; not fluid or gaseous

solstice (sŏl'stĭs): the periods when the sun appears to remain for a few days at noon at its highest point (about June 21) and its lowest point (about December 21) as seen from the Northern Hemisphere

solubility (sŏl'ū bĭl'ĭ tĭ): state of being able to dissolve

solution: a liquid containing a dissolved substance

sounder: the portion of a telegraph receiver which is struck by the moving armature and thus makes the clicking sounds of dots and dashes

sound track: a narrow strip along the left-hand edge of a piece of motion picture film; it is a photograph of the vibrations of a beam of light which has been set in motion by a source of sound

spark plug: a plug fitting into the cylinder head of a gasoline engine in which is produced the electric spark that ignites the explosive mixture in the cylinder

spectrum (spĕk'trŭm): an arrangement of rays of light or other forms of radiant energy (such as radio waves, infrared rays, ultraviolet rays) according to the wave length

sperm: a male sex cell which unites with an egg cell during fertilization

spiracles (spī'rȧ k'lz): breathing openings in the bodies of insects

spirillum (spī rĭl'ŭm): one type of bacterium, so named because of its spiral shape

spore: a thick-walled plant cell which can withstand unfavorable conditions, for example, lack of water, warmth, and food

stabilizer (stā'bĭ līz'ẽr): a mechanical device on the tail of an airplane to balance the plane

stalactite (stȧ lăk'tīt): an icicle-shaped deposit hanging from the roof or sides of a cavern, formed from dissolved materials left by water

stalagmite (stȧ lăg'mīt): a deposit on the floor of a cave formed from dissolved materials left by water dripping from the ceiling

stamen (stā'mĕn): the male reproductive organ of a flower, produces pollen grains

star: generally refers to a sun so distant that it appears as a point of light even when seen or photographed with the aid of a telescope; however, our sun is a star

starch: a nutrient which is insoluble and must be digested

static electricity: charges of electricity produced by friction

steam engine: an engine driven by the energy of steam

stimulus (stĭm'ū lŭs): anything that causes a temporary increase of activity in a living body or any of its parts

stomach poison: a chemical, such as arsenic, which is mixed with food, thereby killing insects with chewing mouth parts

stomate (stō'māt): a microscopic opening between cells in a leaf, found more often on the undersides of the leaf, through which air and water vapor pass

storage battery: a voltaic battery whose energy is restored by passing an electric current through its cells

storm windows: extra windows added outside regular windows

stratosphere (străt'ō sfēr): the middle region of the atmosphere between the troposphere and the ionosphere

streptomycin (strĕp'tō mī'sĭn): a chemical produced by certain soil bacteria which slows down or stops the growth of certain bacteria (useful against tuberculosis)

strip cropping: a farming method in which several types of plants are sown in alternate strips

suspension: an insoluble solid suspended in a liquid; for example, soil in water

sweat gland: a gland in the skin which excretes a fluid composed of water, salts, and urea onto the skin surface by means of ducts

symbol: a one- or two-letter abbreviation for the name of an element

synthetic (sĭn thĕt'ĭk) **rubber:** rubber that is made by chemists from petroleum products

tektite (tĕk'tīt): a type of meteorite which some scientists believe may have been dislodged from the moon's surface by the impact of another meteorite

television: a method of communication whereby visual images are transmitted and received

terraces: steplike embankments built of soil, to prevent slipping or erosion of soil during heavy rainfall

textile (tĕks'tĭl): a woven fabric

theodolite (thē ŏd'ō līt): an optical instrument which can be used to measure the height and speed of clouds

thermograph (thûr′mō gråf): a device used to make an automatic and continuous record of temperature changes

thermometer: an instrument for measuring the temperature at a particular moment

thiamine (thī′ȧ mēn): a vitamin of the B complex, formerly called vitamin B_1, which prevents beriberi

third-class lever: a lever in which the force is between the fulcrum and the resistance

thrust: the forward motion given to an airplane by its propeller or jet engine

time capsule: a metal tube buried in the earth containing records and samples of the things of present-day civilization and intended to be opened in the future

tissue: a group of similar cells performing the same function; for example, muscle or nerve tissue

topsoil: the upper fertile layer of soil, containing humus, which is necessary to support plant life

tornado (tôr nā′dō): one of the most violent of windstorms noted for its funnel-shaped cloud, high-speed winds, and great destructiveness over a short path and small area

total eclipse: the complete hiding of one heavenly body by another or by the umbra of the shadow cast by another

toxoid (tŏk′soid): a weakened or diluted toxin which, when injected into an animal, causes the organism to develop antitoxins

trade winds: the northeast trade winds blow from the vicinity of the Tropic of Cancer toward the equator; the southeast trade winds blow from the vicinity of the Tropic of Capricorn toward the equator

transmission (trăns mĭsh′ŭn), **automobile:** a device which transfers the motion of the automobile engine into several speeds of forward motion and one of reverse motion

transmitter (trăns mĭt′ẽr): the part of a communications device which sends out the signals intended for a distant receiver

trichina (trĭ kī′nȧ): a parasitic roundworm found in the flesh of animals, causing trichinosis

tropical cyclone: a violent storm originating in the tropics and commonly called a hurricane or typhoon

troposphere (trŏp′ō sfēr): the lowest portion of the atmosphere, the part in which we live

tungsten (tŭng′stĕn): a heavy, white, ductile, metallic element used in making electric lamp filaments and tungsten steel

turbine (tûr′bĭn): a rotary engine moved by pressure of steam or water

ultrasonic: refers to high pitched sounds above the range of human hearing

umbra: the darker portion of a shadow

uranium (ū rā′nĭ ŭm): a heavy, white, radioactive element occurring in an ore called pitchblende (see **pitchblende**)

Uranus (ū′rȧ nŭs): a planet of the solar system between Saturn and Neptune; Uranus has five moons; it is barely visible to the naked eye during a moonless night

vaccination (văk′sĭ nā′shŭn): the process of injecting a vaccine to produce active immunity

variety: a group of organisms which are distinguished from others by an inherited difference

vein (vān): a soft blood vessel, containing valves along its length, which carries blood from the body to the heart

ventilation: the free circulation of air into, within, and out of an enclosed area so that there will be a continuous supply of fresh air

ventricle (vĕn′trĭ k'l): one of two muscular chambers of the heart which pump blood to parts of the body

vent valves: valves in a submarine that allow air to escape from ballast tanks as water rushes in

Venus (vē′nŭs): a planet between the earth and Mercury; Venus is the brightest planet and it has no moons

vertebrates (vûr′tē brāts): animals which possess backbones, either of cartilage or bone

vibration (vī brā′shŭn): a rapid forward- and-back motion

villus (vĭl′ŭs): a tiny fingerlike projection of the lining of the small intestine, used for absorption of digested food

virus (vī′rŭs): a large protein molecule, smaller than the smallest known bacterium; viruses cause many diseases

vitamin: a chemical found in foods and needed in small quantities for special body functioning; lack of a vitamin causes a deficiency disease

vocal cords: folds of the lining of the voice box, or larynx, which may vibrate when air passes over them

volcano: an opening in the earth surrounded by materials thrown out of the opening

volt: the unit for measuring electric pressure

voltaic (vŏl tā′ĭk) **cell:** an arrangement for generating electricity by the action of a chemical upon two dissimilar metals

voltmeter: an instrument for measuring electric pressure in terms of volts

vulcanizing (vŭl′kăn īz′ĭng): the process of treating rubber with sulfur to improve its strength, hardness, elasticity, etc.

warm front: the boundary between a mass of advancing warm air and a retreating mass of relatively cooler air

warm-blooded animal: a bird or mammal whose body temperature does not vary with changes in the temperature outside its body

water cycle: the continuous changes of water — evaporating from the surface of the earth (oceans, lakes, streams, etc.) into water vapor,

eventually forming clouds and condensing as rain, then flowing back into lakes, streams, oceans

water erosion: the dissolving of chemicals by water from soil and rocks as well as the transportation of soil by water

water table: the surface of ground water soaked deep into the soil

watt: the unit for measuring electric power

wave length: the distance from the crest of one wave to the crest of the next or from any point in one wave to the corresponding point in the next wave

weathering (wĕth′ẽr ĭng): the gradual destruction of material exposed to the weather; wind, moisture, sunlight, heat, and cold are the chief causes of weathering

wedge: a piece of wood or metal, tapered to a thin edge, used to split or raise heavy objects

wheel and axle: a device consisting of a grooved wheel with an attached axle, used for lifting heavy objects

white blood cell: the type of blood cell which helps to destroy bacteria and other foreign particles which enter the body

wind erosion: the wearing away and transportation of soil and rock fragments by wind

wireless telegraphy (tḗ lĕg′rȧ fĭ): a method of communication now commonly known as radio; it was originally called wireless because no wire connected the transmitter and the receiver

work: the product of a force times the distance the force moves a body, usually measured in foot-pounds; work is done whenever a body is moved or its motion is stopped by a force

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